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One might be surprised that the outcome of the Rio+20 Summit this past summer still had the power to disappoint both civil society stakeholders and engaged policy makers. Despite all the knowledge and experience gathered since 1992—perhaps even since the publication of Limits to Growth two decades earlier—about the worsening state of the earth’s ecosystems and the increasing inequity within and between countries, the global political language and mindset remained resolutely committed to growth. While sustainable development was a shared hope at the 1992 Rio gathering, in June 2012 governments around the world focused on “sustained growth.”

Contrary to the general thrust of the conference, some civil society groups long involved in global policy processes began to cultivate an alternative effort prior to Rio+20 to articulate the measures and actions required for a movement toward a genuinely sustainable future. This process morphed into the Peoples’ Sustainability Treaties (2012). The objective of the treaties is to focus on post-Rio+20 processes, while building on many years of work already done globally. The questions around which the treaties are coalescing are: what needs to happen during the post-Rio period to initiate a global transition toward an authentically sustainable future? What would we, as civil society and acting collectively, like to see happen over the next few years, despite what governments and corporations may or may not do? Are there actions and commitments that we, collectively and individually, feel obliged to make regarding our own responsibilities toward the future? If, for whatever complex set of reasons, governments choose not to act, what should our own response be?

Among the fourteen treaties that have emerged to date is the Peoples’ Sustainability Treaty on Consumption and Production. For those engaged in the formulation process, the message is quite clear: economic growth, as a recipe to cure all the world’s ills, will certainly fail to deliver, given the macro-scale constraints on the system—the ecosphere. All the weak approaches discussed and implemented to date to encourage sustainable consumption and production—by focusing on consumers as active market actors, by encouraging the purchase of greener or more efficient products, and by promoting so-called win-win solutions—are far from sufficient. Efficiency and market-based strategies are surely useful principles for, as the treaty conveys in its subtitle, “transforming livelihoods and lifestyles for the well-being of all.” Nevertheless, the idea of efficiency, which is necessary but ultimately inadequate to meaningful action, must be subsumed within a set of more expansive principles that are often neglected:

- **Equitable Consumption:** Facilitating a fair but limited share of the planet’s resources for all people on earth.
- **Well-being:** Provisioning the conditions for fulfilling basic needs, which are necessary (but hardly sufficient) for a good life.
- **Sufficiency:** Engaging in life from a sense of personal wholeness, rather than an unthinking longing for material acquisition and the mindless accumulation of wealth.
- **Sustainable Societies:** Ensuring social equity and ecological balance by appreciating the well-being generated outside markets from household production and voluntary work.
• **Decentralized Governance:** Enabling sustainability to generate resilience at the community level. Governance should build on the principle of subsidiarity and recognize a real need for global, supranational, and even national action. However, it is important to emphasize that actions for sustainability should devolve to the lowest effective level of governance. Local efforts should take priority over global action, but it is important to recognize that all local action is predicated on the enablement of global action.

Based on these principles, the treaty calls for commitments by governments, business, international organizations, and the scientific community. The backbone of this call, however, are the commitments and the actions proposed by civil society organizations (CSOs) themselves. The underlying approach is to better mobilize civil society—instead of individual consumers—to claim their rights as citizens for re-structuring the world’s economies toward sustainability. This would be done through:

- Promoting sustainably localized lifestyles by setting examples, for instance in transportation, food supply, housing, leisure, and financial management.
- Campaigning for sustainable lifestyles while rejecting existing modes of advertising and media promotion of wasteful and materialistic living.
- Engaging actively in politics and policies at all levels of governance.
- Influencing businesses to behave more sustainably through buyers’ actions that support a sense of sufficiency, respect for ecological limits, and implementation of policies that promote restraint on consumption and wasteful production.

Countless people have fortunately already started on paths toward sustainable consumption and production by, for example, engaging in local food cooperatives or public gardening, provisioning services with explicit sustainable character, participating in neighborhood centers, and joining alternative currency schemes. These are among the social innovations building the foundation for strong sustainable consumption. They constitute the development projects out of which a sustainable global future will grow and inspire a new narrative where a feeling of contentment builds the mental and emotional models for experiencing a good life for everyone and where caring and responsibility, instead of individual self-interest and consumerism, are the underlying values. Signatories to the treaty commit to supporting the development of such initiatives powering an expeditious way forward. Depending upon the respective focus of each signatory organization, they commit to:

- Stop appealing to consumerist and materialistic values and conceptual frames (e.g., economic growth and nationalism) for short-term gain, knowing that these tactics create long-term harm by reinforcing a culture of materialistic consumerism. Instead, we commit to supporting local initiatives and to facilitate learning exchanges for the new economy.
- Develop internal capacity within all organizations for new economic thinking and integrate this knowledge into our own strategies and visions.
- Engage and provide opportunities for a wide participatory dialogue around a new narrative of sustainable consumption and production. This narrative has to be made concrete by millions of people empowered to develop shared leadership. Future civil society campaigns will gain from more participatory processes and the notion of shared leadership.
- Cooperate much more actively with successful change agents who can be found at all levels and who are developing the seeds of the emergent new economy. These individuals and organizations require support for their innovations to spread and to become institutionalized.

That the treaty is in a process of ongoing development became clear at the Peoples’ Summit held in Rio in parallel with the official United Nations Rio+20 Conference. While a separate treaty supporting the development of a set of “Millennium Consumption Goals” (MCGs) was originally planned by the supporting circles of the MCGs, attendees decided during one of the public meetings to integrate these goals within the broader framework of the Peoples’ Sustainability Treaty on Sustainable Consumption and Production.

But let us return to the treaty process more generally. The most surprising, as well as the most encouraging, aspect in this variety of activities is that all of the diverse communities approaching sustainability—from the “Rights of Mother Earth” to “Sustainability in Higher Education”—emphasize three basic elements:

- **Equity and sustainability for all** are the overarching demands from civil society and must be the foundation of any collective global response.
- **Localizing our systems of economies, decentralizing governance, and advancing sustainable lifestyles and livelihoods** become inte-
gral to the new social order of sustainable societies. Localism is the theme emerging across the board, which is linked to the principles of devolution of power, decentralization in action, and subsidiarity in governance. Turning localism into a global movement becomes the key to unpacking many of the complexities we face.

- **A global citizens movement** is the collective response toward transitioning to a sustainable world and to linking the local with the global. All sections of society must converge around their visions and convictions and find common ground for collective action that can bring about the transformation required to ensure the well-being of all on the planet—humans as well as nature—and the envisioning of a new global governance order.

We are delighted to report that these are the real messages to take away from Rio+20 and to build upon in future activities. And in this light, much that is good and strong emerged from the conference, over and above the official documents.

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ARTICLE

Convergent and divergent learning in photovoltaic pilot projects and subsequent niche development

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A proposed strategy to facilitate the use and development of radical new sustainable technologies is the creation of niches. Learning in these niches and the social embedding of learning experiences can stimulate changes in existing sociotechnological regimes. Pilot projects in which new technologies are used may form part of these niches. This article describes the results of a Dutch research project involving photovoltaics on learning within pilot projects and subsequent actions of the participating parties. The central questions are whether and how internal processes, such as open and creative negotiations, foster learning and how such learning relates to subsequent niche developments. The study suggests that pilot projects could encourage both convergent and divergent learning, depending on whether participants’ learning experiences and expectations of the new technology start to align. Although the two types of learning can coexist, they seem related to different process conditions. The implication of these findings is that the management of pilot projects to contribute to regime change involves strategic choices about stimulating either the opening or the closing of the novelty’s interpretative flexibility.

KEYWORDS: learning, technological change, solar cells, renewable energy resources, development projects, management

Introduction

Renewable energy technologies such as photovoltaics (PV) can play a major role in the move toward sustainable energy provision and use. At the same time, the relatively new approach of strategic niche management (SNM) offers a policy instrument for challenging existing sociotechnological regimes and thus stimulating increased application of radical sustainable technologies (Raven, 2005; Schot & Geels, 2008). Originally developed in the Netherlands, the SNM approach can also serve as an analytical framework. Notable examples of early work on SNM include Rip (1989) and Schot et al. (1994; 1996).

The starting point is that large-scale application of a radical new technology is possible only if severe bottlenecks can be overcome. The existing sociotechnological regime—the rules according to which existing technologies are considered self-evident (become locked-in)—typically hinders the introduction of novel technologies. Changes are therefore required in scientific knowledge, engineering practices, production processes, product characteristics, competencies, established user preferences, infrastructure, and so forth (Schot et al. 1994).

The conceptual idea of SNM, which aims to overcome lock-in, is grounded in quasievolutionary theories of technological change in which variation and selection are no longer seen as independent processes and in related notions of technology assessment that aim to manage technological development (Schot, 1992). Historical research confirms that initially many ultimately successful technologies were applied in small isolated parts of the market, so-called market niches (Schot, 1998). These are small application domains in which a novel idea already has some specific advantages over the established technology, although the innovation and its associated user preferences require further development (Hoogma et al. 2002). In these niches, incipient technologies have the opportunity to mature while new ideas evolve about their meaning, user preferences, desirable product development, needed infrastructure, and unexpected effects. The development and specification of these ideas are called learning processes. If market niches do not come into existence spontaneously, but a new technology is expected to have high societal advantages, then a government or company could create a protected niche by providing shelter (e.g., through the provision of a subsidy) to facilitate the process of bringing a technology into actual use.

Scholars of SNM regard niches as potential starting points for sociotechnological regime change, although they have typically assumed that the chance to contribute to such transitions is quite small. The central dynamic is considered to be niche branching,
a process in which niches arise and grow, while a specific new technology is applied in an increasing number of market segments. It is a coevolutionary process in which changes in the knowledge of actors, user preferences, and infrastructure occur in tandem with consistent changes in technology. Geels (2002) provides the example of the substitution of sailing ships by steamships, which started in small niches such as inland waterways and ports and for mail transport. The complete substitution of sailing ships ultimately came with mass emigration from Europe to the United States and the opening of the Suez Canal (which was not amenable to sailing ships).

In the early SNM literature, the main transition dynamic of regime change is thus regarded as an incipient technology that ultimately substitutes for an incumbent technology via a process of niches branching out, growing, and eventually replacing the regime. This process occurs if the niches align with, and are strengthened by, changes in the regime that are induced by pressure from external developments at the macro-scale (or landscape) level, such as an economic crisis, a natural disaster, or a particular demographic change (Weber et al. 1999; Kemp et al. 2001), with the consequent destabilization of the incumbent regime.

More recent analysis of transition processes has focused on interactions among developments at the three different levels of analysis: the micro-scale niche, the meso-scale regime, and the macro-scale landscape (Raven, 2005; Smith, 2007; Schot & Geels, 2008). In response to the critique that the niche approach overemphasizes micro-scale developments as the core locus of change, Geels & Schot (2007) developed a typology of ideal typical transition pathways. In addition to the substitution trajectory, they, for instance, distinguish pathways in which niche innovations are adopted as add-ons to the existing regime. In each of these pathways, it appears that both an opening of new opportunities (by a proliferation of niches) and a closing down (with one or a few niches becoming dominant through a process of selection) play roles.

Questions persist regarding the relationship among deliberate protection of niches, learning, niche branching, and regime change. Furthermore, the analytical framework of the niche approach remains based mainly on conceptualization of past regime shifts that came about without any intervention (or niche management, as we would say now). We are also unable to draw many conclusions from existing, deliberately managed niches (for instance, from subsidized experiments with new forms of sustainable transportation) because they have not had the time to contribute to regime change (Hoogma, 2000; van Mierlo, 2002; Raven, 2005). Whether the historic processes around autonomous niche development and regime change can be taken as starting points for deliberate niche management therefore remains to be seen. In this regard, there is a need for more empirical elaboration and testing of the niche approach.

Recent work on sociotechnological innovation pleads for more research on learning in niches and the wider influence of these protected spaces (Schot & Geels, 2008; Smith et al. 2010). In this article, learning is the key concept for understanding niche developments from a micro-level perspective. I propose to address learning by probing into a protected niche, and even further down to the level of single pilot projects, to clarify whether and how it is possible to deliberately foster learning in and around such projects to stimulate niche development with the ultimate aim of contributing to regime change (cf., Brown et al. 2003). It is assumed that the success or failure of pilot projects in the sense of learning is neither merely reliant on external prerequisites—such as subsidy programs, pressure from policy measures, and so forth—nor simply dependent on the characteristics of the novelty and the way it is applied in the project. The aim is to discover whether social processes internal to the pilot projects, such as network formation and negotiation, have a significant influence on learning. It is also of interest for the management of pilot projects to know whether such learning indeed influences subsequent niche development via further actions of the participating actors. For reasons explained in the next section, the analysis focuses on convergent learning, which occurs when diverse actors “develop visions on solutions and problems that complement one another, and change their roles and goals in close association with each other” (van Mierlo et al. 2010a).

The central questions of this article are:

- What internal processes influence convergent learning and further actions in and around pilot projects involving the actual use of PV in housing?
- What is the relationship between learning in pilot projects and subsequent niche development via actions of the participants?

I first define the central concepts and discuss the analytical framework in the following section. The third section describes PV in housing, the applied technology at the center of the analysis. This discussion is followed by descriptions and a comparative analysis of four PV pilot projects in the Netherlands with particular attention devoted to their learning processes and their conditions for learning. In the final section, I draw conclusions on the management of pilot projects and niches.
A Framework for Analyzing Innovation in and around Pilot Projects

Niches appear in many forms, but practical experiments, as well as protection measures, are often integral to such innovation-facilitating spaces (Hoogma et al. 2002). However, not all experiments and projects for learning and innovation can be evaluated from the perspective of the SNM approach. To distinguish these experiments from others, such as experiments in the laboratory that hardly trigger learning on social aspects like user preferences and division of roles, the term pilot projects is used. I define a pilot project as an initiative of a group of diverse actors to apply a new, radical technology in practice (with or without protection) in a specified market segment that at least one of the relevant actors views as promising. In cases where end-users are not involved during the development phase of the project, they become engaged in the near-natural context once the technology is applied.

For analytical purposes, a clear distinction must be made between a single pilot project and a niche that may consist of a several such initiatives, various experiments, and other activities and processes. A pilot project is bound in place and by a particular set of participants, and these boundaries are quite clear to the relevant actors. For this reason, Brown and her colleagues prefer to refer to such activities as “bounded sociotechnical experiments” (Brown et al. 2003; Brown & Vergragt, 2008). Furthermore, the actual application of the technology requires a tangible form of cooperation, since a diversity of actors must come to some kind of agreement to proceed (van Mierlo, 2002). Such collaboration is not necessarily the case for the interaction of actors within a niche around several experiments. It is consequently important to investigate the negotiation process inherent in a single experiment and its role in the development of the niche.

Participants in pilot projects have the opportunity to learn. In addition, further niche development may occur in a very specific way, for instance, if the participants are encouraged to apply a new technology in a subsequent project.

To clarify the influence of the internal processes among participants in a single pilot project on learning and further actions, I investigated several pilot projects in the same protected niche. I did so with the aid of an analytical framework that was, on one hand, focused on the desirable effects of pilot projects and, on the other hand, the conditions for learning. The latter provided insight into the management of pilot projects that aim to contribute to regime change.

Direct Effects of Pilot Projects

To enable evaluation of the pilot projects, criteria were formulated to empirically examine each initiative at the project level. In line with the niche approach, as well as the work of Brown et al. (2003) and Brown & Vergragt (2008), learning in projects is the starting point of the analysis. The three criteria of direct effects of pilot projects are convergent learning, organizational adjustments, and repeated use.

In the context of the empirical cases, most of the participants engaged with a new technology with which they were not previously familiar. What does that mean from a learning perspective? Most literature on learning in niches and innovation projects focuses on what is called second-order learning, which is distinct from first-order learning (Hoogma et al. 2002; Brown et al. 2003; Smith, 2007; Brown & Vergragt, 2008; van Mierlo et al. 2010b). First-order learning involves gaining experience about how to do things better within the framework of pre-existing goals and assumptions; it alone would not contribute to regime change. In contrast, more demanding second-order learning occurs when basic aspirations, values, and assumptions become the subject of learning. Such learning is assumed to be essential for regime change. Both learning concepts apply to individuals, homogeneous groups, and organizations and were originally developed to study the adaptation of organizations to changes in the environment (Argyris & Schön, 1996). However valuable they may be, this article proposes another concept of learning to evaluate PV pilot projects, namely convergent learning, because it sheds light on learning among people from a diversity of organizations and groups with heterogeneous roles, problem definitions, aspirations, and values.

Convergent learning entails aligning project participants’ interpretations and actions about how to apply the new technology, to divide the roles in project development, to handle risks, to manage the project, to finance extra costs, to respond to complaints, and so forth. This concept of convergent learning is useful because a pilot project resembles a negotiated agreement between several different types of actors put into action (Drake & Donohue, 1996). Successful negotiations require the development of relatively stable interdependence messages early in the process and shared interpretations, or at least an alignment in meaning (Dewulf et al. 2009). Conversely, when disputants cast the issues in incompatabile ways and fail to create an acceptable joint framing, conflicts are often perpetuated (Salipante & Bouwen, 1995).

Moreover, the concept is relevant for analyzing a project’s influence on further developments over time. What lessons were learned and what conclu-
sions were drawn for subsequent activities and about the future of the new technology? Again, alignment is central given that every transition becomes coordinated at some point via the synchronization of visions and the interconnection of actors’ practices and roles (Callon et al. 1992; Geels & Schot, 2007). The terminology of convergent learning illuminates the prospect of complementarity among the fundamentally different assumptions and values of the various project participants. They do not necessarily come to share a completely common view during the learning process; it suffices if their perspectives overlap partially or are mutually supportive. The concept is inspired by Grin & van de Graaf’s (1996) idea of congruency, that heterogeneous actors in a policy network may come to regard a particular line of action as a meaningful solution to a problem differently experienced by each of them. In a pilot project, heterogeneous participants may come to convergent learning, operationalized as the development of complementary visions on the desirability and feasibility of the (future) use of the novelty in a certain application domain and their own roles in its further development from their respective (changing) aspirations and values.

The second direct effect relates to the idea that the formal and informal rules guiding actions in innovation projects are initially diffuse, broad, and unstable (Schot & Geels, 2008), while niches consist of an emerging community in which rules gradually become more specific, shared, and stable. It is assumed that rule changes as a direct effect of pilot projects are restricted by the actors that are involved in them and by the limited scale. It is for this reason that organizational adjustment is the central criterion used, assuming that a successful project leads participants to adapt their internal organization in such a way that it advances their own and other actors’ engagement with the new technology (van Mierlo, 2002). A participating energy company, for example, might decide to rescind restrictive rules on feeding back PV electricity into the grid, thereby making it easier for individual households to take advantage of the technology.

Direct additional application of the technology, for instance in follow-up initiatives, is another desirable effect of a pilot project. This idea is inspired by, but does not completely follow, Rogers’ (1995) concept of adoption: a decision to make use of one innovation out of several possibilities. I analyze the action following such a decision as repeated use of the novel technology in new projects.

### Conditions Conducive to Learning and Subsequent Niche Development

This study defined three criteria for identifying beneficial learning conditions that expose the ways in which project managers can stimulate convergent learning, organizational adjustments, and repeated use in pilot projects: heterogeneous network formation, open and creative negotiation, and network management.

First, heterogeneous network formation is seen as an initial internal condition for learning. Callon et al. (1992) provide a relevant perspective on network formation, suggesting that technoeconomic networks around new technologies should fulfill different functions—those of science, technology, use, regulation—and mediate among the actors performing these activities. The network of participants in a PV pilot project certainly consists of actors with different functions and roles, such as investing, subsidizing, developing products, using the products, providing advice to users, and so forth. I investigated to what extent the network around a pilot project was heterogeneous, in the sense of the diversity of functions fulfilled by the participants, who came from both existing regimes and a potential new PV regime.

Second, as suggested earlier, the participants in a pilot project have to come to an agreement and a form of coordinated action to be able to apply the technology. Therefore, the analytical framework deployed here is based upon a theory, principled negotiations (or consensus building), that elaborates on negotiations fostering deep learning and innovation (Fisher & Ury, 1993; Susskind et al. 1999; Innes & Booher, 2010; see also van Mierlo et al. 2010b). The central focus of this perspective is on high-quality agreements that meet the desires and priorities of all actors, are based upon knowledge and expertise, and often are more innovative than regular accords (Innes, 1999). In addition, the negotiations required to reach these agreements have important secondary effects like fostering learning, building new and trusting relationships, and forging novel practices and rules.

These agreements can be reached in negotiation processes that are self-organizing in the sense that there is consensus about the process rules. Because participants discuss their respective stakes and other aspects that are usually taken for granted, these negotiations creatively ensure that the resulting agreement is more than just a division of the cake. Moreover, they are open: participants gain insight into their partners’ interests, motivations, points of view, and so forth. These characteristics are summarized in the condition of an open and creative negotiation process.
The final condition is network management. It is assumed that managing a pilot project that aims to stimulate an innovation process differs significantly from traditional forms of project planning or operational steering, both of which tend to focus on preset goals, efficiency, and content (van Mierlo et al. 2010a). Project managers should take the characteristics of complex networks into account, as well as the nonlinearity of negotiation processes (de Bruijn & ten Heuvelhof, 1995; de Bruijn et al. 2010). If the managers of the PV pilot projects take demonstrable action to form a heterogeneous network and facilitate open and creative negotiations, they are presumed to be managing the network.

The Emergence of a Protected Niche for PV in Housing

Many products can be made and several social functions can be fulfilled with PV. From an historic point of view, the first niche for PV emerged when solar panels were used in outer space. Since the 1980s in the United States and the 1990s in other industrialized countries, PV has been portrayed as a sustainable alternative to electricity produced with fossil fuels. The United States, Germany, Japan, the Netherlands, and other countries developed government programs to stimulate both development and use of PV (see, e.g., Jacobsson et al. 2004).

In the Netherlands, a White Paper released in 1990 proclaimed that in two decades grid-connected PV could become the most important sustainable energy option (Ministerie van Economische Zaken, 1990). Prior to this document the national government did not expect PV to be relevant for Dutch energy provision, but upon its release a target was set to save two petajoules (PJ) of fossil fuels per year by 2010 with PV systems. Between 1994 and 2000, the government saw new housing as the most promising market segment for PV, given the abundant roof space available and its accessibility via developers that build large housing projects. With a sizable budget for a special learning program, Dutch policy aimed to investigate under what conditions a large-scale introduction of PV in housing would be feasible (Novem, 1994: 1997) during a period when the costs per kilowatt-hour (kWh) for PV were about ten times the consumer price for customary electricity generation. For the learning program, Novem, an organization that acted on behalf of the Ministry of Economic Affairs, provided a project subsidy to large organizations because intervening in a market of numerous private households was expected to be managerially too complex. Energy companies in particular could receive a subsidy if Novem was convinced that the proposed projects would be useful for learning about the technical and social bottlenecks and possibilities of PV. A major condition was that large solar systems would be integrated into the roofs of buildings for aesthetic reasons. In addition, the government expected that saving regular roofing material would reduce the costs for the PV systems in the long term. As a consequence, the learning projects were targeted toward new housing developments. For the Netherlands, where local governments allocate land to project developers, this meant that governments and developers were both involved in these initiatives. It became the role of architects to integrate PV into the design of the new homes.

At the start of the learning program in 1990, there was only one house in the Netherlands with a large autonomous PV system on the roof. This system was built by a solar energy enthusiast committed to demonstrating that PV was suitable in the country during a period when the national government still assumed it was not feasible. In addition, PV was being installed in approximately 25 privately owned homes with grid-connected systems and a further ten rental homes that were part of a project pursued by an electric utility company (van Mierlo, 2002). From these sparse beginnings, the learning program had, by its termination in 2000, financially supported the realization of about 150 projects (Verhoef et al. 2001). Thousands of PV houses were built with the aid of the learning program and a new subsidy for small PV systems. Over the course of the decade, the previously dominant role of energy companies was reduced; ownership of the systems shifted from the energy companies to the residents and project developers began on their own initiative to apply for subsidies for PV housing projects. The power capacity of all grid-connected PV systems in the Netherlands was almost 9 MWp (megawatt-peak) in 2000 and increased further to 89 MWp in 2010 (Statistics Netherlands, 2012).

Although this amount was still far from the hundreds of MWp needed to reach the national policy goal, the Netherlands in 2004 came to occupy fourth position among European countries in terms of PV capacity per inhabitant. However, between 2003 and 2010, the annual added volume of PV fell dramatically due to a political shift in the country. The government reframed earlier subsidies for PV as being cost ineffective compared to wind energy and as stimulating free riding (Negro et al. 2009). As a consequence the Netherlands dropped in 2010 to fourteenth position among European countries. However, in the same year the Dutch PV market rose again in response to a temporary new subsidy, but its future prospects remain highly uncertain because of the incessant inconsistency in Dutch energy policy.
The learning program in general followed the course advocated by SNM scholars and provided room to learn in practice about a radical new technology in heterogeneous networks. Even though the learning program came to an end long before any signs of a regime change, it provided a useful opportunity to look more closely at the learning processes among the many actors, including PV companies, housing developers, and energy companies, that were closely involved in these large pilot projects.

With the idea of applying and integrating large PV systems in buildings, the radical, challenging character of PV became obvious. In the words of Geels (2004), niches are increasingly radical as they deviate more from the rules of the dominant regime. All sociotechnological regimes consist of a plurality of explicit and implicit principles of how to produce and use the new technology embedded in norms and values, physical infrastructure, formal regulations, consumption patterns, and so forth. If integrated into buildings, PV becomes an energy-production unit as well as a building element that requires new standards and procedures and changes in existing rules in both domains.

Decentralized energy production with renewable energy demands drastic changes in the relationship between energy companies and their customers, who used to be end-users and now become producers. To make grid connection possible for feeding back surplus PV electricity at times of high production, Dutch energy companies had to develop norms for the required quality of the PV-produced electricity and the return rates (van Mierlo, 2002). Technological developments across production, distribution, and energy use—such as a redesign of the grid for dynamic demand management, new forms of transportation power, and large-scale energy storage—are needed for decentralized renewable energy options (Huberty & Zysman, 2010). Unruh (2000) speaks of a carbon lock-in, a vicious cycle in which governments allow lock-in, a vicious cycle in which governments allow and use the new technology embedded in norms and values, physical infrastructure, formal regulations, consumption patterns, and so forth. If integrated into buildings, PV becomes an energy-production unit as well as a building element that requires new standards and procedures and changes in existing rules in both domains.

Investigation of the process conditions for learning in pilot projects and the further actions of participants is based on a comparison of four housing initiatives with PV in the Netherlands. Completed between 1995 and 1998, these initiatives formed the first phase of a series of large pilot projects, which are comparable in the sense that they all commenced during the same period and were all part of the same protected niche—PV in new housing projects. Given this or less similar context, comparing the projects allows for study of the influence of internal processes on learning and subsequent actions of the participants.

There were, of course, important local differences among the four pilot projects. Table 1 provides an overview. In two of the projects, the systems were owned by the residents while in the other two schemes ownership was in the hands of the energy company. Three of these projects—in Amsterdam, Apeldoorn, and Amersfoort—involved large roof-integrated systems. In these efforts, each PV system was meant to produce at least 50% of the annual electricity use of an average household. The fourth project, also in Amersfoort, involved mounting one alternating current (AC) solar panel on the roofs of hundreds of houses. It was the first time that such a

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Amsterdam</th>
<th>Apeldoorn</th>
<th>Amersfoort</th>
<th>AC project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of PV houses</td>
<td>71</td>
<td>94</td>
<td>50</td>
<td>217</td>
</tr>
<tr>
<td>Total power (kWp)</td>
<td>250</td>
<td>219</td>
<td>110</td>
<td>22</td>
</tr>
<tr>
<td>Costs (minimum in €)</td>
<td>2.4</td>
<td>2.3</td>
<td>1.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Subsidy (%)</td>
<td>49</td>
<td>58</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>PV ownership</td>
<td>energy company</td>
<td>residents</td>
<td>energy company</td>
<td>residents</td>
</tr>
</tbody>
</table>
small PV system had been applied in the Netherlands.

The extensive files of the project managers provided the start of the empirical research for three of the pilot projects and offered a useful way to analyze the chronology of important events, the times of formal decisions, and the arguments used by participants. The direct effects of the pilot projects were analyzed in detail by means of in-depth, semi-structured interviews with all the participating actors, including the managers of the energy companies, architects, and key representatives from the PV suppliers. In total, 43 interviews were conducted with several respondents (the project managers and representatives of the PV supplier) involving more than one session.

**Learning a Great Deal in Amsterdam**

When the energy company in Amsterdam took the initiative to apply PV in a new housing project in 1991, just the one other example (with PV panels integrated in the roofs of ten rental homes) was available in the country to serve as inspiration. The announcement by the Dutch government that it wanted to subsidize large PV projects stimulated this scheme. The energy company’s motives were to experiment with this promising new technology and to fulfill its legal environmental obligations. By fortuitous circumstance, the energy company was already in contact with the local government, which was then in the process of designing an environmentally friendly new housing development and for which implementing PV seemed an attractive addition. The municipality of Amsterdam decided to organize a competition for project developers and their architects to create a plan for a new housing project including PV. The energy company formulated a long list of prerequisites for the application of PV, such as the generation capacity (in kWp), the tilt, and the orientation of the solar panels. A requirement was that the systems would be physically integrated into the roofs.

There were numerous confrontations between the vested and new actors around these prerequisites as well as other matters. According to the energy company, the project developer and the architect neglected the requirements with respect to optimal production of PV electricity, such as the orientation and the tilt. Discussions took place both during the design stage and the construction phase. There was, among others, a huge debate about the height of the chimneys and the shadows that they would cast over the solar panels, thereby decreasing efficiency considerably. In a similar vein, the energy company and the only Dutch PV producer at the time, Shell Solar Energy, paid scant attention to the difficulties and the relevant knowledge of the project developer and architect. According to the project leader from the municipality, “The energy supplier had no experience with building projects, the process. They hadn’t thought about the social consequences, about the reasons for a project developer to participate in such a project” (Heere, 1996). More fundamentally, the desire on the part of the energy company to achieve an optimal yield conflicted with the values of the project developer and the architect (as well as with the values of the municipality) regarding building aesthetics and residential density.

For example, it took almost a year before the energy company was willing to pay for the additional time that the architect needed for the design due to its newness and difficulties with the physical integration of PV, such as knowledge of tilt and orientation and material characteristics. Another problem concerned the sizes of the panels, which did not fit the standards common in building projects and were not as tolerant of adverse weather conditions as other material alternatives. Despite an earlier technical test of the integration technique, rain started to leak into the houses immediately after they had been built, probably because of problems in the connection between the regular roof material and the solar panels. In the end, an expensive approach involving the installation of a watertight subroof proved to be the only reliable and acceptable solution.

It required nearly six years to complete this large PV housing project and at first sight the effects were slight. Only two of the participating actors changed their policies and procedures: Shell Solar Energy employed a building expert and started to cooperate with electrical engineers and Novem decided to manage the projects on the basis of criteria rather than involvement in all project discussions. Hence, only the participants whose main interest was in PV were induced by the pilot projects to undertake organizational adjustments relevant for the introduction of PV. In addition to these two actors, only the architect continued to work with PV in subsequent projects, as he was convinced of the possibilities for PV in housing developments despite its high costs. He also changed his vision on housing fundamentally when he decided to put “room for nature” at the core of all his new projects. The rest of the participants perceived the project as a single, stand-alone venture.

In line with the conceptual assumption that without an open and creative negotiation process a pilot project will not lead to the desired effects, there was little sign of convergent learning in this project. Except for Novem, Shell Solar Energy, and the architect, none of the participants believed that PV was sufficiently mature to be applied in new housing developments. The energy company no longer saw an active role for itself in such initiatives; instead, it decided to start a test with small systems in existing
housing. The visions of the participants did not come much closer, except for their opinion that the PV houses were beautiful and that future residents needed to be financially involved with the PV systems. All relevant actors, except for Novem, stated explicitly that they had not learned from one another.

However, if one looks at the project in more detail, an interesting effect can be seen. Although the participants did not learn in a convergent way, all of them learned broadly about many aspects of PV in new housing: financial, technical, aesthetic, and social. The energy company learned about the accurate placing of chimneys, leakage problems, electrical requirements, financing, building processes, and division of responsibilities in the event of problems. Although Novem still expected energy companies to take an active and initiating role in large PV projects, the energy company itself had come to a different conclusion. The project developer learned, among other things, that he should take shadowing into account and that a roof should have margins without PV. The municipality learned that, although the houses were attractive, PV was too expensive to be applied and that the residents should derive personal benefits from the PV systems attached to their houses. In sum, almost all lessons were actor specific, and in some cases contradictory.

**Several Project Managers in Apeldoorn**

Shell Solar Energy, in collaboration with a project developer, took the initiative for another large PV project. The company wanted to show that the national goal of realizing 250 MW of PV in 2010 could best be reached by pursuing large PV projects in housing. It also sought to gain experience with these sizeable PV projects. Together with two other energy companies, Shell Solar Energy formulated the general prerequisites and identified the feasibility of a large project with about 100 PV houses. A project group was formed that started looking for a suitable location somewhere in the Netherlands. It took about two years to find an appropriate site and two years longer to complete the terms of reference among the collaborating companies about preconditions, planning, and financing, which were never actually signed. It was the project developer who finally contacted the municipality of Apeldoorn, where the PV objective fit the planning of a new housing estate called Energy Zone.

Because of long, drawn-out financing problems, the project developer at some point threatened to build the houses without PV with the aim of forcing the decision-making process. In the same period of stagnation, which was partly due to employee turnover at the one energy company that remained involved, Shell Solar Energy wrote a memo arguing that the energy company should participate more actively in the project. So, in a way, the PV supplier took the initiative to manage the project.

Except for one of the architects involved, the participants assessed the negotiation process in quite negative terms. As the energy company’s project leader formulated it, “After the conclusion of the project, the fights remained in my head” (Bergsma, 1998). The energy company and particularly the project developer were dissatisfied with one another’s roles, and almost all participants claimed that others were insufficiently interested in PV. With respect to the decisions taken, many participants felt that they had had to forego some of their own aspirations. One point of discussion concerned the payback rates for the residents, who in contrast to the Amsterdam residents would own the PV systems. The energy company suggested the same payback rates as those nationally set for wind energy. Since these were lower than the regular price households paid per kWh, the project developer did not agree and as a consequence let future residents pay less for the PV systems (9% of the total direct costs). Additional problems occurred during the building of the houses. It proved difficult to connect the solar panels to the edges of the roofs, and, because of their weight and large size, the panels bent a little and ran the risk of breaking. Moreover, when finally realized, the PV systems suffered from problems with the invertors and other technical parts.

The Apeldoorn case demonstrates how, despite an unsatisfactory negotiation process, problems can be overcome if participants other than the project leader manage the process at moments of conflict or stagnation. This seems all the more important since, in spite of the difficulties, the project had substantial effects. All participants learned about a wide range of aspects and, above all, after the completion of the project, were convinced that PV systems could be applied in new housing. Some learning experiences were shared, such as the conclusion that residents should have access to the PV electricity themselves and that the installation should be better prepared. Most learning experiences, however, were so diverse that the participants could not easily conceive of a collaborative follow-up project. The energy company learned most about division of responsibility in the development and ownership of the PV systems, the PV supplier learned most about the strict rules in the building sector, and the project developer learned about how to finance such a project. Contradictory conclusions were drawn about the color of the solar panels (beautiful versus ugly), the realization of such a project in practice (complex versus simple), and the best phase to become concrete about financing (early
on versus after participants have become really motivated).

Besides the PV parties, several other participants undertook organizational adjustments. The energy company, for instance, formulated its own quantitative goals for the application of PV and developed new financing instruments to capitalize on the willingness of some clients to pay for clean energy. The project developer started cooperating in the national PV covenant, and one of the architects joined a working group to study cost-reduction measures. In line with these positive effects, most of the parties participated in follow-up projects in several application domains, including both new and existing housing and new office buildings.

A Quite Principled Negotiation Process in Amersfoort

In Amersfoort, the initiative to integrate PV systems into rental houses was taken by the energy company, which had a budget for energy-saving projects that would be supplemented with a subsidy from Novem. The network around the pilot project was formed on the basis of several existing bilateral contacts. Because of these prior connections, the participants trusted one another to some extent at the start. The energy company was already involved in meetings organized by the municipality about guidelines for the infrastructure of a large sustainable housing estate. This area was also opened up for experimental experiments, an opportunity the energy company gladly embraced. The housing association, which was already interested in passive solar energy, was willing to cooperate because of the opportunity it provided for approaching the energy company about extra energy-saving measures.

From the outset, the energy company paid considerable attention to interactions among the various PV-project participants; for instance, a working group for communication was formed involving many of them, including the municipality. The participants agreed on a code of conduct to inform one another about their communication activities. Furthermore, at several stages the energy company asked the participants to join a midterm evaluation. Points of discussion were, among others, the size of the inverters (one per seven houses), whether to use thermal solar energy as well, and the specifications of the contracts between the housing association and the residents who would not own the PV systems. Also, participants discussed many aspects of the original design of the houses, given their influence on the yield, until the designs were satisfactory to all concerned. When the contract builder made clear why he did not have confidence in the selected integration technique, although it had been tested, the project group decided to change it. The building-and-use phase faced numerous complications because of a lack of contact between the energy company and the contract builder and insufficient knowledge on the part of the builders about the requirements for PV, such as ventilation. Moreover, neither the inverter system nor the profiles for the integration of the solar panels proved to function well. So, as in Amsterdam, a water-tight subroof was needed.

The energy company’s project manager tried to facilitate a process of coproduction and obviously succeeded considering the remarks of other participants. For instance, the project manager of the housing association observed, “I joined the group and aspired to get the feeling ‘we are doing this together.’ It went perfectly…even though a lot of problems arose. Everybody had a very good attitude. If we were in a dip, we said ‘hold on’” (Meijrink, 1996). Most of the participants stated that they were very satisfied with the roles and the positive, cooperative attitudes of others.

In light of these process conditions, the pilot project in Amersfoort proved to have desirable effects. Many new actors who became involved in the project learned extensively and in a convergent way. They all became convinced that it was possible to develop new housing projects with PV in the—by then—existing situation. They also shared many learning experiences, such as that more attention needed to be paid to the connections between the components of the PV system and the house; that one central stakeholder should coordinate the handling of residents’ complaints; and that it was important to involve the contract builder earlier in the process, that is, during the design rather than the construction phase. Since many of these issues were thoroughly discussed during the joint midterm evaluations, they seem to have supported convergent learning. In addition, the project led to some actor-bound learning as well, experiences not mentioned at all by other participants. Novem concluded that it was too early for prefabricated installation, the energy company resolved that it should control the building requirements, and the contract builder expected the prices to drop soon because of the existence of several PV suppliers. The architect and contract builder did not agree on the tilt, because the tilt that was best for PV production, and therefore preferred by the architect, allowed rain into the houses.

A large follow-up project planned from the outset of this first PV initiative in Amersfoort, as well as several nearby PV undertakings by the energy company, offered the participants the opportunity to participate in subsequent activities, which all of them did with the exception of the housing association. In these initiatives, the Amersfoort project contributed...
to niche splitting in several directions: from housing to utility building and from rental houses to owner-occupied houses.

**Little Special in the AC Project?**

The AC project, which entailed the installation of a single solar panel on each of 217 houses, arose from an initiative of a project developer who wanted to have an innovative image. By his own account he noted that, “One square meter of solar cells means nothing of course. It is the banner [status symbol] to your house though” (van Mil, 1997). The project developer wanted to build in the aforementioned estate in Amersfoort, where the municipality required some sustainable energy measures. Other parties were not interested in the option of just one solar panel (in this case an AC module) per house. Since these small systems hardly contribute to the average yearly electricity use of a household, the Dutch government by then considered them to be an inefficient use of free roof space. Also, integrating PV systems physically into buildings was believed to be more appealing aesthetically than adding an AC module to regular roofs. Moreover, at that time, none of the large actors involved in stimulating PV was interested in exploring a private market, given the high costs per kWh. The project developer, however, assumed that, because the price of the module was relatively small, integrating it into the price of the whole house would not be an obstacle for buyers.

Although this type of application diverged significantly from the leading ideas about the value and application of PV in the Netherlands at the time, and the associated techniques for AC modules still had to be developed, the project challenged few rules of the existing building and energy regimes. The AC modules were easy to add to the original design of the houses because they were small and did not have to be integrated. Traditional building relationships were sufficient to pursue the project. The developer served as the manager for the whole project, including installation of the PV panels, and the supplier of the AC modules, again Shell Solar Energy, was selected after comparison of several offers. In this case, the PV supplier was consequently not involved directly in the building project, nor was the energy company, which only formulated the conditions to connect the AC modules to the electricity grid. At the request of the project developer, a consultant undertook the search for a suitable PV application and the technical preparations. During construction, just a few problems with the AC modules became apparent and, as far as is known, there were no special challenges during the use phase.

There were just a few bilateral contacts regarding PV; in fact, there was nothing like a collective, open, and creative negotiation process among the participants. Still, the AC project had considerable effects. All participants became convinced that AC modules could be applied in housing, and several saw how straightforward it was to do so. A negative shared lesson was that the AC modules were visually unattractive, among other things because they did not cover the whole roof. In addition, some participants had their own, mainly technical, learning experiences. Compared to the other projects, the various actors learned very little regarding project management, relations among participants, and interactions with residents.

The project developer, one of the architects, and the consultant all pursued other subsequent projects with private PV systems in new housing developments. The initiative also stimulated actors that had been only indirectly involved, or not at all, to consider approaching a private market with AC modules. The four AC modules concept—the idea to cover 10% of the average electricity consumption of a household with a few panels—arose nationally and was embraced not only by Shell Solar Energy but also by Novem and some energy companies that had not been previously interested. The project thus triggered organizational adaptations not only by the project developer but also by several external actors. In 2000, thousands of existing houses had a small PV system as an add-on, paid for by the residents and subsidized via large-scale projects initiated by Greenpeace and energy companies. Private customer interest, however, remained lower than proponents had anticipated.

**Process Conditions Differentiated**

Comparison of the process conditions in the projects is revealing (see Table 2). A first finding is that a heterogeneous network of participants and associated people was formed around all four PV pilot projects. In all of these initiatives, actors from the existing building regime were involved (project developers, housing associations, contract builders, architects, local authorities, and residents), and in three of them also an actor from the energy regime (the energy company). Actors from the potential new PV regime (the PV suppliers and, in most cases, Novem) participated as well.

However, an open and creative negotiation process was reflected in only one project. In Amersfoort, the participants engaged actively, solved problems collaboratively, handled public relations together, and were open toward one another. This was also the only project in which the energy company, functioning as the project manager, paid serious attention to social processes as a result of network management.
In the other projects, negotiations were not open and creative at all, nor were there obvious signs of network management. In the AC project, however, there was no need for deliberation among the relevant parties because the application of PV in the building project was no challenge at all. The manager of the AC initiative was the project developer, as is usually the case. The way he wanted to apply the PV systems was technically and socially quite simple, because the systems were small and could be installed as add-on components and the costs were nominal compared to the prices of the houses. No special procedures or innovative arrangements (other than technical) were needed. Hence, the extent to which the envisioned project-specific application of the new technology challenges the rules in the incumbent regimes—which I term the ambitiousness of the pilot project—was rather small. It shows that it is not necessarily a technology itself that is radical in the sense that it is confronted with structural barriers in the existing regime; rather it is the characteristics of the envisioned market and the degree to which it diverges from existing regimes that determine whether a novelty is radical or not. It seems plausible, then, to take the ambitiousness of the pilot project into account as a feature that determines the need for open and creative negotiations to stimulate learning.

The projects in Amsterdam and Apeldoorn did challenge many existing rules: by striving to apply large systems in many houses at once, by having the energy company serve as the PV project manager in addition to the overall project manager, and by integrating the PV panels physically into the buildings. A confrontation between vested and new interests took place, as shown in the conflicts about the importance and possibilities of an optimal yield from the PV systems, the implementation problems that occurred because of the lack of knowledge on the part of the PV supplier and the building parties about one another’s procedures and norms, and the tensions about the division of responsibilities and core competencies among the energy company, building parties, Novem, and the PV supplier. In these cases, principled negotiations would have been necessary for convergent learning. However, the negotiations were not open and creative. The PV parties, the building parties, and the energy companies found themselves working on an interdependent basis, without really wanting to be.

Table 2: Process conditions (in italics: process condition not or hardly present).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Amsterdam</th>
<th>Apeldoorn</th>
<th>Amersfoort</th>
<th>AC project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heterogeneous network</td>
<td>Actors from the building sector, energy company, local authority, and PV parties.</td>
<td>Actors from the building sector, energy company, local authority, and PV parties.</td>
<td>Actors from the building sector, energy company, and PV parties.</td>
<td>Actors from the building sector and PV parties.</td>
</tr>
<tr>
<td>Ambitiousness of pilot project</td>
<td>Very high</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Open and creative negotiation process</td>
<td>No one felt ownership of the process. A lot of conflicts, not really resolved, mutual incomprehension. Choices and decisions tolerated without participants being convinced.</td>
<td>Some participants did not feel ownership of the process. Some important participants unsatisfied with process. Choices and decisions merely tolerated.</td>
<td>Special approach of project, partly developed by participants. Open negotiations, not really creative. Satisfaction about decisions.</td>
<td>No special procedure. No multilateral negotiations, just bilateral. Decision-making process was conventional.</td>
</tr>
<tr>
<td>Network management</td>
<td>Mostly management of content.</td>
<td>Hardly any network management; instead, management by a number of actors.</td>
<td>Several characteristics of network management.</td>
<td>Traditional project management.</td>
</tr>
</tbody>
</table>
Table 3: Direct effects on pilot-project participants (in italics: no or little effect observed).

<table>
<thead>
<tr>
<th>Learning Mode</th>
<th>Amsterdam</th>
<th>Apeldoorn</th>
<th>Amersfoort</th>
<th>AC project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONTRIBUTING TO REPLICAATION IN THE NICHE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organizational adjustments</td>
<td>Adjustments conducted by only two PV parties.</td>
<td>Adjustments conducted by five participants.</td>
<td>Adjustments conducted by five participants.</td>
<td>Adjustments conducted by two actors from the existing regimes.</td>
</tr>
<tr>
<td>Repeated use in same market segment</td>
<td>Architect only building party that became involved in new pilot project.</td>
<td>Almost all participants undertook new projects.</td>
<td>Almost all participants undertook follow-up projects.</td>
<td>Almost all participants involved in new projects.</td>
</tr>
<tr>
<td><strong>CONTRIBUTING TO NICHE SPLITTING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Divergent learning</td>
<td>Participants learned much about diverse subjects with several contradictory learning experiences.</td>
<td>Participants learned much about diverse subjects with some contradictory conclusions.</td>
<td>Many actor-specific learning experiences, one contradictory.</td>
<td>Some actor-specific learning experiences, none contradictory.</td>
</tr>
<tr>
<td>Exploration of different market segments</td>
<td>Test in new potential market segment: existing houses by energy company.</td>
<td>Use in office sector, existing houses, and others.</td>
<td>Use in office sector and other ownership relations.</td>
<td>No repeated use or tests in different market segment.</td>
</tr>
</tbody>
</table>

**Direct Effects under the Influence of the Process Conditions**

In a comparison of direct effects (convergent learning, organizational adjustments, and repeated use), three out of the four projects were successful: Apeldoorn, Amersfoort, and the AC project. In contrast, the Amsterdam initiative displayed none of the predefined desirable effects. However, when we look at the implications of this project more closely, it becomes clear that, even though no convergent learning took place in Amsterdam, some learning actually did occur. In fact, all the participants learned a great deal about the possibilities, value, and constraints for PV in housing. Their learning experiences were, however, very diverse and did not lead to complementary visions about the desirability and possibilities for the future of PV in new housing developments. It seems useful therefore to consider divergent learning as a direct learning effect, separate from convergent learning. Whereas convergent learning means that visions and actions around a novelty align because of experiences in the pilot project, in the case of divergent learning various changes occur in participants’ thinking, but they are purely actor-bound, sometimes deviating from, and at times even contradicting, one another. In conflict situations, divergence can be treated as a continuation of the status quo, but in innovation processes, the emergence of divergence can be seen as an articulation or learning process. So with divergent learning, participants’ visions change without the coherence needed for subsequent coordinated actions.

Defined as such, divergent learning is observable in three of the four cases to a greater (Amsterdam and Apeldoorn) or lesser (Amersfoort) extent. In the AC project, by contrast, there was convergent learning about the application of PV in new housing developments since there was alignment of the learning experiences of the participants about a restricted set of subjects, but there was no additional divergent learning.

A similar distinction between diverging and converging effects was found across repeated uses in the same potential market segment or in another one. The AC project stimulated several participants to use PV again, but only in the same application domain (i.e., types of buildings, ownership conditions, type of PV system), whereas participants in the other projects started using PV in other application domains (Table 3).

Divergent learning and use in other domains seems to approximate what Bijker (1995) called the interpretative flexibility of an artifact. This terminology means that diverse actors and groups interpret the technology in varying ways as a solution deriving from their own problem definitions, leading them to explore it in disparate ways. In a similar vein, convergent learning, organizational adjustments, and repeated use in the same domain relate to what Bijker calls closure—a reduction in the diversity characterizing a new technology due to negotiations and coalition building. The coexistence of convergent and
divergent learning in two projects suggests that the process of closure within these projects was not complete at the time.

In sum, whatever the differences in the quality of the negotiation process and the network management, all projects were relatively successful. At this point, the discussion turns to a more detailed analysis of the relationship between the process conditions and the learning effects. In each pilot project, the formation of the network was heterogeneous. Since this result is in line with theoretical assumptions, it is still assumed to be a general condition that requires further research.

Other conditions were dependent on the kind of effects considered desirable and the ambition of the pilot project. Divergent learning took place in all of the ambitious projects, so challenging many regime rules may be a condition for this type of learning. For convergent learning, heterogeneous network formation sufficed in the more mundane AC project. For the projects that challenged many rules (Amsterdam and Apeldoorn), an open and creative negotiation process and network management were great advantages for convergent learning. However, these factors cannot be seen to constitute vital process conditions. In Apeldoorn, management by a number of participants appeared to replace these conditions to a greater or lesser degree.

Conclusion

This article has sought to provide insight into the process conditions for learning and follow-up actions by and among the participants of pilot projects with a new technology. Both these effects are relevant from the viewpoint of innovation and regime change. How did the participants give meaning to their experiences in the design phase of the pilot projects and the construction of the buildings, and did their visions align and motivate them to participate in similar subsequent initiatives? The following discussion summarizes the main findings of the empirical case studies and identifies some consequences of this work, both with respect to theoretical perspectives on the role of pilot projects in regime change and to the formulation of strategies to enhance niche development by protecting specific application domains.

Internal process conditions in the PV pilot projects influenced learning among the various parties involved in the new housing developments. It is apparent that the importance of process conditions depends on 1) the kind of learning (convergent or divergent) and 2) the ambitiousness of the pilot project.

An unexpected outcome of this study is that the pilot projects differed in the degree to which they challenged prevailing rules in the incumbent energy and building regimes. The level of ambition seemed to act as a sort of intervening factor. In the three challenging projects, a greater number of process conditions was required to reach success in terms of convergent learning and follow-up actions than in the more routine project. Furthermore, high ambition may have been an important process condition for divergent learning. These results suggest stimuli for interactive learning in innovation processes that go beyond the better-known ones of external crises and surprises, bringing in new knowledge and diverging perspectives, trust and reciprocity, and feelings of urgency and interdependency (Argyris & Schon, 1996; Aarts & van Woerkum, 2002; Leeuwis, 2004; van Mierlo et al. 2010b).

These observations raise many questions about the scope of the findings from the selected PV cases. Additional research is needed, for instance, regarding whether divergent learning can also occur in relatively mundane projects. The process conditions for learning may depend on the application domain and the stability of the relevant regimes. Moreover, the process requirements for subsequent actions, which are essential for regime change, most certainly reside not only within the pilot projects but in the direct context as well. The relationships between second-order learning—the central concept used in innovation studies—and convergent and divergent learning are unidentified and call for further inquiry (see also Schot & Geels, 2008).

However, comparison of the PV case studies provides strong evidence for the value of distinguishing convergent from divergent learning as important processes in pilot projects that aim to contribute to regime change. Moreover, the clustering of opening and closing effects justifies formulating the implications of the findings for pilot projects and niche development.

At this point, it is instructive to return to the notion of niche branching. According to the niche approach, niche branching is a key feature of the successful introduction of radically new technologies. No distinction is made between the splitting of a niche toward another potential market segment and replication of a niche (in the same market segment) in another geographical area. Niche branching can mean both. As Hoogma and his colleagues (2002) observe, “This process of niche branching includes the emergence of new application domains and the creation of a bandwagon effect through replication of the niche elsewhere.” However, the term chosen—branching—suggests that splitting is regarded as the main process.

Evaluation of the PV pilot projects indicates that niche splitting and replication in a niche are different processes. Given the results of this study, they may
well be accompanied by different types of learning in and around pilot projects and seem to have different process conditions as a consequence. Convergent learning, the type of learning that is the most promising for regime change from a theoretical point of view, was found in the PV projects related to replication in a niche and not to niche splitting. So it is all the more relevant to specify analytically types of learning and types of niche development and their respective process conditions, and to study the role of these processes in the interaction of the projects with the regime and in diverse transition paths at a more general level (Geels & Schot, 2007; Smith, 2007; Klerkx et al. 2010).

The pilot projects in Amersfoort and Apeldoorn seem to have the characteristics of what Smith (2007) calls intermediate projects, given that the PV niche and incumbent energy and building-regime actors mutually adapted their visions and rules. The AC project can be seen as a typical example of a translation process in which lessons and newly developed practices in the pilot project were easily transferred into the existing regimes, albeit not because of their flexibility but because of their relatively low level of ambitiousness.

For the management of pilot projects, and probably niches as well, the results of the study entail some strategic choices. A first choice is whether the ambitiousness of a pilot project, or a series of pilot projects, will be high or low. This choice is strategically relevant because, on the one hand, high ambition may be deemed necessary to avoid an exclusive focus on incremental changes and, on the other hand, it may hinder reaching desirable effects in a pilot project because of inherently high risks due to uncertainty about the amount and availability of resources, actions of competitors and suppliers, future changes in policy, and so forth (Meijer & Hekkert, 2007).

A second choice is whether or not to aim deliberately at the opening or closing of interpretative flexibility associated with the new technology. Opening seems a more likely impact of an ambitious pilot project because, as in the case of PV in new housing developments, it does not require a deliberative and creative process or an engaged management style in the same way that closing does. However, some niches (like PV in housing) are protected, with the aim of stimulating a specific application domain that is expected to have potential in the long run. In those cases, aiming to stimulate participants to apply the technology again in the same domain may be at least as important as having them explore other application domains. The challenge then is to encourage ambitious projects to come to closure by providing the necessary additional process conditions.

The management of pilot projects and niches is thus not merely a matter of imitating the dynamics of spontaneous historical regime changes that start with the emergence and branching of market niches in small application domains where the new technology is expected to have advantages in the short run. Rather, the historical lessons about the natural routes toward regime change must be drawn on in thoughtful and flexible ways.

Acknowledgement
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Carbon calculators as a tool for a low-carbon everyday life?

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The number of Internet-based carbon calculators that estimate personal carbon footprints has been growing in recent years. This article discusses the roles that these calculators can play in changing everyday practices and how users evaluate them. The study builds on results from a questionnaire survey and focus groups with users of a Danish Internet-based carbon calculator developed in 2009, the year of the Climate Summit in Copenhagen, when climate change was prominent on the political agenda. The article concludes that the subject website primarily attracts people already interested in the issue, and that its main contribution is to confirm their engagement. Furthermore, we show, on one hand, that users seem to accept the individualized approach of the carbon calculator while, on the other hand, they question the allocation of responsibility for mitigating climate change. The article suggests designing Internet-based carbon calculators that actively engage users in collective actions instead of primarily presenting individualistic interventions. Finally, we show that users are different with respect to which of their everyday practices they feel able or inclined to change, with air travel being the practice that, by far, they are least willing to alter.

KEYWORDS: emission reduction, social behavior, social responsibility, Internet, computer applications, communication

Introduction

At least since the Brundtland Commission released its report on sustainable development in 1987, numerous public efforts have been directed toward educating and persuading people to change their everyday-life habits to make them more sustainable. These campaigns have typically been based on an assumption of causal relationships among beliefs, attitudes, and behavior and have employed what Hargreaves et al. (2008) have termed the “A-Bc model” (Attitude-Behavior connection) or Shove (2010) has called the “ABC paradigm” (Attitude, Behavior, and Choice). Adopting a rather individualistic approach, these campaigns typically focus on providing information through mass media and leaflets to inform people about the environmental consequences of their behaviors—for example in relation to transportation, housing, and food—and to encourage them to change behavior by informing them about more ecofriendly alternatives.

Following this line of thinking, many researchers have come to understand the absence of sustainable behavior as resulting from a value-action or attitude-behavior gap (e.g., Blake, 1999; Young et al. 2010) primarily caused by a knowledge deficit, which can be bridged by creating appropriate information campaigns. Policy makers widely believe that providing consumers with feedback about their energy consumption will induce energy reduction; however, research shows that this is only the case to a quite limited extent (Fischer, 2008; Darby, 2010).

During the last decade, numerous websites have been developed that include calculators to estimate personal ecological footprints or carbon use. Evaluations of these tools carried out to date have primarily focused on their accuracy, and several studies have shown large variations in the results generated by different calculators (Padget et al. 2008; Kenny & Gray, 2009; Kim & Neff, 2009). Evaluations of other communication initiatives also suggest that disseminating new knowledge does not necessarily lead to changes. People question the knowledge and compare it with their own experience, and new practices also need to fit in with established practices in everyday life (Hobson, 2001; Gram-Hanssen et al. 2007). Research also shows that direct communication, for instance with an energy professional, is much more effective than public campaigns in inducing actual changes in people’s practices and thus reductions in their carbon-dioxide (CO2) emissions (Hargreaves et al. 2008). Further, new behaviors are often more likely to transpire if they are introduced in social networks, for example within the context of low-carbon communities, that can serve as a context for individual behavioral change (Heiskanen et al. 2010).

In summary, studies indicate that simple one-way dissemination of information has a limited effect because changes in practices happen through an interaction with adjustments in collective structures rather than through individuals’ isolated actions and because information in itself does not automatically lead to changed everyday practices. The problem is, however, that initiatives, including direct contact and
joint intervention in collective processes, are expensive and complex, which might explain the preference for mass communication.

In this article, we evaluate a Danish mass communication initiative (an Internet-based carbon calculator) intended to support sustainable behavior. The analysis is inspired by the practice-theoretical approach developed by Schatzki (1996). Practice theory is further developed in the next section; here we describe how this conceptual approach seeks to overcome the structure-actor dualism regarding whether human behavior is primarily determined by social structures or individual agency. Based on this approach, we do not expect any simple relationship between disseminating new knowledge and the change of individuals’ daily habits. However, as developed in the following discussion, the practice-theoretical approach does acknowledge that information and new knowledge can play a role in constituting everyday-life practices. Thus, our main interest is not to document a simple relationship between using the carbon calculator and changes in practices. Rather, the purpose is to understand to what degree and how websites, such as the one evaluated here, might contribute to structuring the knowledge and meanings that govern the different habits that give rise to CO2 emissions. On the basis of users’ experience, we also suggest how this type of website could be improved to better facilitate changes to a low-carbon everyday life by viewing ordinary practices as collective rather than individual activities.

Understanding Change and Continuity in CO2-Related Everyday Practices

Recent years have seen several efforts to use a practice-theoretical approach to understand everyday practices related to energy consumption. Social-practice theories stem from the work of Bourdieu (1976) and Giddens (1984) and were reintroduced in consumer studies some years ago (see, e.g., Shove & Pantzar, 2005; Warde, 2005) following the argument that hitherto there had been undue focus on conspicuous consumption, and the symbolic and communicative aspects of consumption, at the expense of understanding routinized and ordinary provisioning responsible for the majority of energy use (Gronow & Warde, 2001). The emphasis on bringing practice theories into consumer and environment studies mainly draws on the approach formulated by Schatzki (1996) and further elaborated by Reckwitz (2002). Practices are not viewed as individual acts, but rather as collective actions where the individual can be viewed as a carrier. This understanding of practitioners as carriers of practices can be aligned with the concept of “habitus” from Bourdieu (1998).

Habitus describes the embodiment of practices and dispositions and thus explains why we tend unconsciously to repeat structures and collective practices based on what we have learned and been exposed to during our lifetime, from childhood to adulthood. More recent practice-theoretical approaches discuss the elements holding these collective practices together. For an understanding of energy-consuming everyday practices, Gram-Hanssen (2010a; 2010b) has developed an approach that has proven valuable in previous studies, and which includes the following four elements:

- **Know-how and embodied habits**: Includes all the unconscious routines that people might have learned during childhood or later and that they bring with them and perform every day without conscious thought.
- **Institutionalized knowledge and explicit rules**: Includes technical knowledge and cultural understandings of energy consumption and energy saving, thus also comprising the types of knowledge disseminated through information campaigns.
- **Engagements**: Refers to the ends people are seeking to achieve. In relation to everyday life and climate change, the problem is that most often energy-consuming practices are governed by engagements other than environmental considerations. People turn on the computer to work or communicate, but at the same time they generate CO2 emissions.
- **Technologies**: Refers to washing machines, computers, cars, and many other energy-consuming technologies that have become an inseparable part of most daily practices such as laundering, communication, and transportation. Technologies thus play an important role in constituting the practices related to CO2 emissions in everyday life.

It is the first element (know-how and embodied practices) that, together with technologies, forms the direct link between practices and energy consumption; it is through our bodily habits (“the way we do things”) and our interaction with technology that flows of materials and energy are activated. Concerning an analysis of websites, focus should thus be on whether these tools are able to change consumers’ engagements or the knowledge and rules related to everyday practices in ways that influence know-how and embodied habits or the type of technologies that we choose to buy.

Another way to frame the same question is proposed by Wilk (2009) who developed an analytical approach based on practice theory in which unco-
conscious habits and routines can be made “visible” and subject to reflection and discussion through the process of “cultivation.” There are many ways to foster cultivation. Other people can make us aware of habits that we do not think about ourselves; we can experience conflicts between different routines that make it necessary to make a conscious choice or adjustment; or—as in this study—media, websites, and advertising can present information that calls common routines into question.

While cultivation denotes the process of bringing habits and routines forward into consciousness and reflection, Wilk uses the concept of “naturalization” to describe “the processes which push conscious practices back into habitus, or keep them from surfacing into consciousness in the first place.” Wilk distinguishes between two processes of naturalization: submersive and repressive. In many cases, practices never surface from the realm of unconscious routines (habitus) because they are so widespread and closely associated with our cultural understanding of “normal behavior” that it takes great effort to make people aware that these practices are contingent and can be subject to changes. Examples are the energy-consuming practices related to comfort and cleanliness. For example, highly controlled indoor temperatures and daily showers are perceived by most people as “simple necessities” that cannot be contested. Wilk calls this “submersive naturalization” and by this he means “that the routine remains thoroughly submersed in the habitus.” However, we would like to add that submersive naturalization might be better understood as a characteristic of some practices more than as a “process of naturalization.” In a sense, what Wilk calls submersive naturalization seems to be a kind of “inertia” related to some practices that makes it difficult to bring them into consciousness and discourse. These habits and practices—and the understandings associated with them—seem to have an almost ontological status, which might also explain why questioning the relevance and validity of such habits is often felt as an attack on one’s personal identity and entire way of living.

The other type of naturalization, according to Wilk, is “repressive naturalization,” which describes the methods we employ to force a practice back into habitus if alternatives have challenged it or if it is a new practice that we intend to turn into a normal routine. For instance, if we want to change our diet for health or environmental reasons, we are engaged in repressive naturalization. Another relevant example is when people legitimate their rejection of the train as an alternative to air travel with reference to socially acceptable rationales such as saving money and time (see below for a more detailed discussion of this case).

Following this line of thinking, it is relevant to focus on how change and continuity in practices can be understood from a practice-theoretical perspective. This includes looking at the balance between routinization and reflectivity as well as ways to understand the role of new technology and infrastructure in introducing change in consumer practices (Gram-Hanssen, 2011). Thus, the main question is to what extent websites like the one studied here actually support changes in practice. This has a number of related subquestions. One is to what extent the website engages people already interested in changing habits versus those not previously interested. Do these websites even reach those with the most environmentally harmful consumption practices? Another question is whether there are different aspects of everyday life where people are more or less reluctant to change their habits and what the causes might be for this resistance. Finally, the reaction of people to the underlying idea of the website, and to the idea that they should feel responsible for their personal carbon footprint, also holds interest. Behind this question is the understanding that practices are not decided and performed by individuals as much as individuals are carriers of practices.

The Website “Map My Climate”

In December 2009, Copenhagen hosted a large United Nations-sponsored climate-change conference. Many different parts of Danish society and numerous organizations and companies were engaged in related campaigns and activities during the months leading up to the event. The Map My Climate project analyzed in this article was one of these initiatives. The cornerstone of this effort was the publicly funded website Map My Climate that enabled visitors to calculate their personal carbon footprint.¹ The website included a so-called “quick test” that allowed users to enter their personal consumption within seven overall categories: heat, electricity, automobile transportation, nonfood commodities, air travel, use of second home, and food. If so inclined, users could also create a detailed and more accurate profile of their energy-consumption practices in the “detailed climate profile” section. Based on this information, the website provided users with tailored recommendations on how to reduce energy consumption in the so-called “my slimming treatment” section. Finally, users could compare their personal carbon footprint with the climate scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) and view potential outcomes of climate change in different

¹ See http://mapclimate.dk.
areas of Denmark with regard to increasing temperatures and flooding.

Launched during the summer of 2009, the website was still running three years later at the time of the preparation and publication of this article. The project sponsors developed a cooperative relationship with the Danish Broadcasting Corporation (DR) that entailed promotion of the website in radio and television programs. DR also had a version of the “quick test” on its own website and this feature enabled users to compare their carbon footprint with famous people from the media.

Methods

Evaluation of the website included both quantitative and qualitative methods. The quantitative part of this study used a counter to monitor the number of website visitors and a questionnaire accessible from the website. The qualitative facet included three focus groups with invited participants. The two approaches were complementary, as the survey provided information about overall tendencies in users’ interpretation of the website, while the focus groups offered detailed insight into these interpretations.

Users visiting the website could access the Internet-based survey via a link called “Tell us about your consumption.” Survey participants were eligible to win a photovoltaic-powered mobile phone charger and were informed that their answers were part of a research project evaluating the website. The survey was open from mid-October to mid-December, 2009. A total of 220 respondents completed the survey, and most of them provided an email address allowing us to contact them two weeks later with a link to a follow-up questionnaire. Ninety-nine users completed this subsequent survey. The first questionnaire included questions on the duration of each user’s website visit, how it had influenced them, their attitudes and knowledge about climate change and everyday practices before the visit, and some questions about their socioeconomic status. The follow-up questionnaire further inquired whether users had actually changed any practices to reduce their carbon footprint or whether they thought they would do so in the future.

More than 14,000 users visited the website during the months of October, November, and December of 2009; thus only approximately 1.5% of these individuals answered the questionnaire. Furthermore, the respondents were self-selected, so caution is needed when interpreting the survey results. In the analysis, we describe the respondents’ main socioeconomic characteristics and discuss to what extent generalizations can be made on the basis of the survey.

The focus groups were carried out in three different communities: a wealthy suburb north of Copenhagen (Hørsholm) where focus-group participants were approached in the higher income neighborhoods with detached housing, a district characterized by modest incomes from the inner part of Copenhagen municipality, and nonurban residents from a provincial town (Kalundborg) with an average income distribution. Income distribution from the three municipalities is shown in Table 1.

These different locales were chosen to secure a diverse social profile of the participants. For each focus group, 40–50 letters were mailed out to chosen neighborhoods and the residents were contacted by phone afterward. In total, this procedure recruited ten initial participants. Especially in Copenhagen, we encountered recruitment problems and therefore used local personal networks to supplement our pool of respondents; however, only “friends of friends” of the researchers were contacted to ensure that the researchers had not met the participants beforehand. Despite the risk of bias, we ended up with a diverse group of respondents in Copenhagen, including participants with no or a short-term education as well as with a long-term education. However, the Copenhagen group was comprised of a significant subgroup of university students made up of five of the thirteen participants.

Altogether, eighteen participants took part in the focus groups (ten females and eight males). In Copenhagen, all thirteen confirmed attendees showed up. In Hørsholm, only two of the seven confirmed attendees appeared due to a snowstorm, and in Kalundborg only three of six confirmed attendees were on hand. Because of these circumstances, the focus groups partly took the shape of a semistructured qualitative interview, particularly in

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Table 1 Income distributions in 2009 in selected Danish municipalities compared with the national average as percentage of population (Statistics Denmark, 2011).

<table>
<thead>
<tr>
<th>Annual Income</th>
<th>National Average</th>
<th>Copenhagen</th>
<th>Kalundborg</th>
<th>Hørsholm</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; €20,000 (US$25,000)</td>
<td>26</td>
<td>28</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>€20,001-32,299 (US$25,000-40,000)</td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>18</td>
</tr>
<tr>
<td>&gt; €33,300 (US$40,000)</td>
<td>49</td>
<td>46</td>
<td>48</td>
<td>60</td>
</tr>
</tbody>
</table>
Hørsholm. Nonetheless, all three focus groups brought important insights, and accordingly, together with a commitment to a tight timeline, we decided not to further reschedule the focus groups.

The focus-group participants were a diverse assemblage with regard to age, socioeconomic characteristics, and family situation. None of them worked professionally on energy or environmental issues or were active members of grassroots activities or environmental nongovernmental organizations (NGOs). The participants in general expressed positive attitudes with regard to the relevance and importance of the climate problem, with none voicing extreme positions that could be characterized as climate-change denial. According to a 2010 survey, 90% of the Danish population agrees that global warming is a human-induced phenomenon (CONCITO, 2010).

The aim of the focus groups was to provide detailed descriptions of how users experienced the website and to what degree the information on it encouraged them to reflect on their own everyday practices and the possibilities of saving energy and reducing their related CO₂ emissions. According to Halkier (2008), the design of focus groups depends on whether analytical attention is primarily on the content (participants’ personal stories and descriptions) or on interactions among the participants (normative negotiations between participants concerning wrong or right behavior). In this study, the main focus was on the content, as we wanted the interactions to generate detailed descriptions of participants’ individual experiences with the website. However, we also intended to create space for normative discussions in situations where they seemed particularly important with respect to motivation (or lack thereof) to change daily behaviors.

Discussions in the focus groups were structured around three overall themes: 1) the participants’ prior interest in climate change and their personal carbon footprint; 2) their experience with the website; and 3) how and to what degree the website had made them think about their own habits and motivated them to change routines. Each focus group lasted about 100 minutes and was moderated by two of the project researchers (one male and one female). The moderators’ written notes and audio recordings of the discussions form the empirical basis for this portion of the study. The content of the discussions in each focus group was summarized and organized according to the three overall themes and later analyzed for differences and similarities among the participants’ personal accounts, as well as across the three different focus groups. This evaluation also included an analysis of the negotiations among participants on normative issues. Quotations from the focus groups have been translated from Danish into English by the authors and all participant names are pseudonyms.

As described above, the empirical material does have certain limitations, including the self-selection of the respondents in the survey and the limited number of people participating in some of the focus groups. These caveats partly relate to the difficulties of identifying and contacting website visitors. However, because there is little previous research in this area, our results can be of interest and provide inspiration for future investigations despite the empirical shortcomings.

Results and Analysis

The following two subsections present in turn the results and analysis of the quantitative and qualitative material. Both types of data are then brought together in a general discussion on how websites can facilitate changes in everyday practices.

Analysis of Quantitative Material

As noted above, during the months of the survey (October to December, 2009), 14,000 users visited the Map My Climate website. However, these visits were not evenly distributed throughout the three months. Table 2 shows the distribution of the majority (more than 12,000) of these visits, namely those who visited the “quick test” version of Map My Climate on the DR website. The activity peaks in October and December and these months coincided with the periods when DR advertised the website in its programs. This shows that strong promotion can be useful in motivating people to take such action, but that interest quickly fades.

The 220 completed questionnaires give some insight into the sociodemographic profiles of website visitors. The respondents were relatively equally distributed by gender (48% male and 52% female). There was a strong overrepresentation of middle-aged people with a corresponding underrepresentation of younger and older people; 66% of the respondents were between 30 and 49 years old (com-

Table 2 Number of unique visitors to the “Quick Test” version of Map My Climate on the website of the Danish Broadcasting Corporation, DR.

<table>
<thead>
<tr>
<th>Month</th>
<th>Number of Visitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>October 2009</td>
<td>5596</td>
</tr>
<tr>
<td>November 2009</td>
<td>1250</td>
</tr>
<tr>
<td>December 2009</td>
<td>5502</td>
</tr>
<tr>
<td>January 2010</td>
<td>181</td>
</tr>
<tr>
<td>February 2010</td>
<td>70</td>
</tr>
</tbody>
</table>
pared with 34% of the Danish population). Furthermore, there was an overrepresentation of relatively wealthier persons, as 61% of the respondents had an annual before-tax personal income of more than 300,000 DKK (approximately €40,000 or US$50,000) compared with only 37% of the general population. Similarly, employed respondents were overrepresented, with 77% of the respondents gainfully employed (compared with 53% of the population overall) while 65% lived in detached homes (compared with 60% of the population).

When discussing to what extent this self-reported group represents all 14,000 users, we assumed that those completing the questionnaire were among the most interested in the subject (including an interest in winning a photovoltaic-powered mobile phone charger) and had the largest amount of spare time. With these assumptions, we would not have expected an overrepresentation of those who are employed, have high incomes, or are in a particularly busy phase of life, which may suggest a general overrepresentation of this population among the website’s visitors.

It can also be argued that this is the most relevant target group for communication related to climate change and sustainable consumption, since it has the highest level of energy consumption and thus CO₂ emissions (Gram-Hanssen et al. 2004).

The respondents were asked to identify their levels of knowledge and interest in energy conservation and CO₂ emissions. Fifty-five percent indicated that prior to their website visit they had had a very high or a high degree of knowledge about possibilities for reducing CO₂ emissions. This proportion can be compared with a 2010 survey that showed that only 43% of the Danish population agreed with the statement that they had “sufficient knowledge about how I can contribute to a reduction in the emission of greenhouse gases” (CONCITO, 2010). Thus, respondents considered themselves well-informed about the subject before visiting the website, a point that raises questions about the extent to which the website succeeded in reaching “ordinary people,” one of the campaign’s original goals.

Most survey respondents did not spend much time on the website: the first third indicated that they remained on it for less than five minutes, the second third between five and ten minutes, and the last third more than ten minutes. Assuming that the survey respondents are among those website visitors most interested in the climate-change issue, this result indicates that the majority of the 14,000 visitors have probably spent less than five minutes on the website. The survey respondents were furthermore asked to evaluate the effects of the website: whether it provided them with new knowledge about climate change and CO₂ emissions, encouraged them to do more to reduce the impacts of their lifestyle, and provided new knowledge about personal actions. For all three questions, the majority indicated that the website had succeeded to some or a great extent.

We were interested in developing an understanding with respect to which of the website’s seven consumption areas users were most and least inclined to make changes. Figure 1 illustrates that respondents were most disposed to engage with electricity consumption areas.

Figure 1 Survey respondents’ answers to the question: “Do you think the website will make you change habits related to…” (the seven consumption areas)?

*n = 220 in this portion of the study.

2 While use of second homes shows the largest percentage of people refusing to change habits, this includes many people without a second home, and thus unable to make changes.
Analysis of Focus Groups

The focus groups showed remarkable support for the idea of calculating one’s individual carbon footprint. None of the participants questioned the relevance or legitimacy of quantifying CO₂ emissions related to one’s personal consumption habits. Also, none of the respondents found it difficult to grasp the underlying idea of connecting individual practices with CO₂ emissions and future climate change. This observation indicates that the understandings and ideology behind concepts such as political consumption and ethical or green consumerism have become widespread and naturalized in Denmark.

The conceptual foundation of green consumerism emphasizes consumers’ individual responsibility for the environmental and social consequences of their consumption and for making informed choices among alternative products on the market. Thus, it is assumed that consumers have the capacity and power to choose environmentally friendly products and to reduce the environmental impacts of their personal consumption practices. Green consumerism is an integral part of the turn from producer-oriented to consumer-oriented environmental policies and the concurrent rise of the concept of ecological modernization that took place in Europe and elsewhere during the 1990s (Christensen et al. 2007).

As already indicated, the website is designed in accord with an individualizing approach to environmental problems that emphasizes consumers’ personal responsibility for handling these issues. Even though the focus-group participants did not question the general relevance and legitimacy of this approach, they did point out a number of challenges in relation to the reliability and usefulness of the information on the website. These issues can be divided into two categories: the first concerns the technical details behind the calculation of the carbon footprint (e.g., underlying assumptions, method of calculation, data quality) and thus deals with the question of dependability—whether one could trust the results. The other category relates to how responsibility for mitigating climate change can or should be allocated, asking whether it is fair to delegate to individual consumers primary responsibility for reducing CO₂ emissions related to personal consumption. Despite the latter type of comment, the participants did not query the underlying premise of the individualized approach. Rather, they reflected on what constituted a fair distribution of responsibility instead of the relevance of calculating one’s personal carbon footprint. In the following subsection, we present a more detailed analysis of the two types of commentary.

Reliability of the Website

Many of the focus-group participants were surprised in particular by the level of CO₂ emissions from their consumption of nonfood commodities. However, this observation also gave rise to a critical discussion about the procedures used for calculating the carbon footprint of such goods. Basically, the algorithm was predicated on users’ annual expenditures on nonfood commodities either as the total amount of money spent and the quantity of CO₂ emissions. They mentioned examples of very expensive, but not necessarily “CO₂ heavy,” products such as customized bicycles.

A similar point of critique was raised with respect to the calculation of CO₂ emissions as a result of consuming food. Most participants found the number of predefined options insufficient for choosing a meal that corresponded to their daily diet. Also, some participants compared the CO₂ emissions of different meals and found that the results were inconsistent with their expectations. For instance, a meal...
based on fish was more CO₂ intensive than a meal organized around minced meat. This “finding” prompted them to question the reliability of the results, and they would have preferred that the website had included additional explanations of these outcomes.

In general, the focus groups showed that the participants interacted with the website in a critical-reflexive way. They questioned the underlying assumptions and calculation methods and also interrogated how the website collected information about their daily habits and consumption. In several cases, the participants expressed circumspection about the reliability of the results, especially those that seemed counterintuitive with pre-existing views (i.e., results that contradicted their prior knowledge, understandings, or habits). Thus, unforeseen information seems in most cases to trigger critical reflection regarding the quality and reliability of data and calculation methods. For some users, this process of critique resulted in a desire for further information. However, unanticipated information might, on a long-term basis, play a role in inducing changes in everyday practices, a point that we take up in more detail later.

As discussed, the participants related the information on the website to their own everyday experiences, established understandings, and prior information from other sources. Dealing with a complex phenomenon, such as the relationship between individual consumption and emissions of CO₂, opens up a “Pandora’s box” of details and uncertain knowledge. From a design perspective, some degree of simplification and delimitation is necessary to create an accessible website; thus, designers need to “black box” some of this complexity. However, the critical-reflexive user will often surmise the existence of the underlying complexity that has been “hidden” and this will induce uncertainty regarding reliability.

Comparative studies find substantial differences among various Internet-based carbon-footprint calculators. For instance, a study of six such calculators from the United States, the UK, and Ireland demonstrated that the estimated annual carbon footprint for the same type of three-person household varied between approximately four and nine tons per person, showing a high degree of inconsistency among different tools with regard to total household footprints (Kenny & Gray, 2009). Similarly, a comparative study of ten United States-based calculators found that, given comparable inputs for individual behavior, the results varied by up to several metric tons of CO₂ per activity (Padgett et al. 2008). The authors further note that these inconsistencies may be due to different calculating methodologies and conversion factors. However, Internet-based calculators “frequently lack the level of transparency needed to understand the reasons for these variations,” a point of criticism similar to the one put forward by several focus-group participants.

**Allocation of Responsibility for Mitigating Climate Change**

Questions pertaining to who has foremost obligation for reducing CO₂ emissions—governments, industries, municipalities, or individual consumers—were recurrent in all three focus groups. The website’s attention to individual consumers’ personal responsibility for mitigating climate change raised these questions. For instance, several of the participants lived alone and felt it particularly difficult to achieve significant reductions in their personal carbon footprints as they could not benefit from “sharing” their consumption of heating, lighting, and so forth. Therefore, they regarded it as unfair to be compared with persons living in households with two or more members. Another example was that of tenants who had limited possibilities for influencing their personal heat consumption, as decisions regarding energy improvements were a matter for the housing association or the landlord.

This is a manifestation of the principal-agent problem of uneven distribution of responsibilities and benefits between agents that has been widely discussed from the perspective of organization theory (see, e.g., Eisenhardt, 1989). A noteworthy expression of this problem is when the tenants pay the heating expenses while the landlord is responsible for investments in energy-efficiency improvements, making it unattractive for building owners to invest in energy renovation. Moreover, participants from rural areas criticized the website for not taking into account that people living in the countryside generally have both a higher need for transportation and limited access to public alternatives. A final example concerns the producer-consumer relationship, as several participants questioned the fairness of including the carbon footprint of, especially, nonfood commodities in their personal CO₂ emissions as the consumer role enables very limited influence on the energy optimization decisions of manufacturers.

Again, these reactions show how the focus-group participants approached the website from a critical-reflexive perspective. Many felt that mitigating climate change entailed a shared and collective responsibility at least equal to the responsibility shouldered by individual consumers. Also, several respondents thought that they would be more inclined to reduce their personal carbon footprints if society, as represented by the government, municipalities, companies, and so forth, were doing more.
Changes in Habits

To explore the new insights the website has provided, we asked the participants whether some of the information had surprised them. Their answers and the subsequent discussion highlighted that, besides the carbon footprint of nonfood commodities, the footprint of food consumption and heating were especially unexpected. However, this newfound awareness did not necessarily result in changes in behavior. Only one participant explained that she and her family had altered their diets after visiting the website, and this was primarily due to her husband who, according to the respondent, was very interested in environmental issues. With regard to heating, most of the homeowners reported that they had already done much to improve the energy efficiency of their homes, while most of the tenants, as mentioned above, felt it was difficult to influence their heating consumption.

Though a visit to the website had limited direct impact on daily practices, many respondents thought that the suggestions about how to reduce consumption and emissions were inspiring. Several also intended to implement at least some of the recommendations, for instance recycling glass, taking shorter showers, and turning off appliances running on standby electricity.

However, participants generally dismissed more extensive recommendations such as eating less meat or reducing car and air travel. In the focus group in Copenhagen, our respondents had a detailed discussion regarding the possibility of reducing their number of flights by choosing other transportation options. This was generally rejected for economic and time-related reasons as well as because of the lack of appealing alternatives. Respondents thought that travel, for instance by train instead of airplane, would be both much more expensive and time-consuming. As a 30-year-old male student explained, he would prefer the airplane as long as “the very CO$_2$-consuming [means “producing”] alternative is cheaper than the little CO$_2$-consuming alternative.” The focus groups thus confirmed the finding from the survey that transportation, and especially air travel, is the consumption area that consumers are least inclined to reduce.

Even though the website seemed to have had a limited impact on users’ daily habits and their motivation for changing them, several survey respondents explained that it had been interesting to learn how ordinary consumption and different habits affect their carbon footprint. Many of them reported that this had been an “eye-opening experience,” which made them more aware of the relationship between their daily habits and climate change. And, as one of the participants explained, to change habits, people “need to be bombarded from many sides.” This indicates that communication by websites, as part of broader information dissemination from other media, might play a role in a long-term strategy to change the elements of engagements and institutionalized knowledge. In the long run, such measures might, in combination with infrastructural and technological adjustments, pave the way for more comprehensive behavior change.

Can Websites Facilitate Practice Change?

Wilk’s (2009) concepts of cultivation and naturalization can help to illuminate some of the dynamics with respect to how users interpret, handle, and use the information provided by the website. Again, the focus-group discussions on air travel are particularly relevant. Some participants were surprised by the carbon footprint of this transportation mode and how much it determines their personal CO$_2$ emissions. Thus, the information provided by the website induced them to reflect on their own travel in a new light and represented a process of cultivation. However, as mentioned earlier, the participants were generally very reluctant to change their mobility practices, especially in relation to holiday travel. They mentioned alternatives such as buses or trains, but rejected them as expensive, time-consuming, and inconvenient. The participants seemed to justify their rejection of these options by referring to a number of widespread and well-established rationalities and ideals in modernity: the faster the better (time efficient), the cheaper the better (economically beneficial), and the more convenient the better (comfort enhancing). This is an example of repressive naturalization, where a practice (in this case air travel), which has been made subject to critical reflection and discussion, is actively forced back into the realm of unconscious routines (habitus) by, in this instance, reference to established rationalities and cultural norms. Another example was the tendency by participants to question the reliability of the output generated by the website (especially the results that the participants perceived as contradicting their own habits). Besides being a relevant and appropriate attitude toward new and controversial information, this can also be interpreted as a way of “disarming” the critical potential of the information, and thus another example of repressive naturalization.

The focus-group discussions about air travel also included an example of submersive naturalization, which relates to deeply (culturally) embedded practices that are difficult to bring into consciousness and, if pointed out by others, are responded to as a personal attack. Interestingly, none of the participants considered the possibility of choosing holiday desti-
nations more proximate to Denmark to avoid traveling by airplane, which apparently was not within their “horizon of possibilities.” When the moderator later mentioned this option, it was immediately dismissed with arguments such as “travelling by air is a pleasure thing that I’m definitely not going to cut down on” and “it should not be [felt like] a punishment to save CO₂.” Suggesting the possibility of limiting the range of holiday destinations due to environmental considerations seemed to challenge basic lifestyle assumptions and evoked one of the most passionate reactions during the focus groups.

This outcome is in line with Calétrio’s (2012) findings of a general refusal among tourists to limit holiday miles due to environmental considerations. As he notes, leisure travel “is an issue of great symbolic and personal value widely perceived to be an essential part of contemporary lifestyles.” This immediate rejection prevented the focus-group participants from further reflections about their choice of holiday destinations and thus exemplified how some practices remain unconscious, or unexamined, through submersive naturalization. The focus groups suggested that holidays are associated with deeply rooted cultural ideas such as freedom and enjoyment, and that strong emotional engagements are associated with the practice of being on vacation. Holidays and air travel occupy a special status in modern everyday and family life, making them the consumption area survey respondents are least inclined to change. This probably relates to the status of holidays as a break away from daily life and, for many, a highly valued time for “family togetherness.” In 2010, the Danish population had 4.4 million long-stay (at least four nights) holiday trips to foreign destinations, and 59% of these trips were made by airplane. Eighty percent of the holiday trips were to destinations within Europe (with Spain being the most popular holiday destination, with 13% of all trips), while only 20% were outside Europe (Statistics Denmark, 2012).

These findings suggest that if part of the aim of communication about climate change is to open for discussion deeply rooted practices that have strong emotional engagement, it is necessary to develop a more sophisticated approach than just quantifying and visualizing the environmental impacts of the practices and suggesting simple alternatives. This tactic risks an emotional “backlash” and a flat refusal as being unreasonable or too radical. An alternative might be to combine information about the size of the environmental impact with a more elaborated discussion about how, for instance, some of the same qualities such as relaxation, time together with family members, or new experiences can be achieved in other less CO₂-intensive ways. This approach would build on the idea of “decoupling” these elements of engagement from the practice of travelling to a holiday destination by airplane and instead “reconnect” these elements with other less CO₂-intensive holiday activities. It would acknowledge that practices are constituted by different elements, including emotional engagements, and to change them it is necessary to combine institutionalized knowledge, such as information about the energy intensity of different modes of transportation, with initiatives directed at the other elements holding practices together. In this case, the institutionalized knowledge could be combined with visualizations of how some of the same qualities (engagements) of air travel-dependent holiday practices could be achieved through other holiday forms. In their study of the development and reinvention of the practice of Nordic walking, Shove & Pantzar (2005) show how elements of practices can circulate and be reconfigured in new ways that represent a reinvention.

With a few exceptions, such as the carbon footprint of heating and food consumption, it was the general experience among the focus-group participants that the website did not provide much new information or many novel recommendations. In this regard, the respondents’ experience reflects the findings of the survey, which showed that a majority of the users considered themselves already well-informed about the subject before they visited the website. This observation is in line with the observation by Hobson (2001) that the low public uptake of recommendations for more sustainable behavior most likely cannot be ascribed to an “information deficit” in relation to environmental issues.

The focus groups indicated that the reason for this low uptake was partly related to the question of who should be responsible for reducing energy consumption. The question of guilt and responsibility kept returning in the discussions, showing its salience. The website, however, was poorly designed with regard to qualifying this discussion, as it almost entirely reflected the ideas of green consumerism, stressing consumers’ individual responsibility. With this one-sided emphasis, the website easily brought the user to a situation of victim-blaming and created a feeling of powerlessness. For instance, living in a society that is increasingly car-dependent, people might find it very difficult to imagine a life without a private automobile. The individual’s need for transportation and choice of means are highly determined by infrastructure and urban planning, and this raises the question of who should be responsible for reducing CO₂ emissions.

Participants’ interaction with the website had more in common with an “active debate” (Hobson, 2001) than with a passive appropriation of information. Active debate is a type of engagement that
“contests the truth and values of the knowledge being presented...and makes use of the knowledge that exists and is mobilised from each individual’s own life and experiences” (Hobson, 2001). In this way, active debate represents a more engaging form of knowledge appropriation through which the individual relates new knowledge to the specific context of his or her own everyday life. This observation supports the active uptake of new knowledge and, as a result, the likelihood that this knowledge will inspire the individual to make changes in his or her everyday practices.

The design of websites for promoting sustainable behaviors should take this observation into account and be crafted to serve as an “interlocutor” that qualifies and inspires the user’s reflections on complicated issues rather than only communicating facts about climate change and behavior. For instance, information about the carbon footprint of different activities such as heating could be accompanied by open-ended questions or statements indicating nuances and complexities related to changing practices of heating and, by so doing, invite the user to further reflection. The principal-agent problem experienced by many tenants in relation to saving energy for heating could be heightened and thus open for users’ reflections on questions pertaining to the allocation of responsibility (in this case between tenants and landlords) and perhaps also provide ideas about how to handle this challenge. And even if the user cannot make practical suggestions, his/her reflections would still have provided a more elaborate understanding of the issue and perhaps, in the long run, increase political pressure to find institutional solutions to the principal-agent problem.

Another example is the previously discussed dilemma surrounding air travel, where facts about CO₂ emissions could be accompanied by questions or statements that invite the user to reflect on what determines his/her decision to travel abroad by airplane and whether some of these objectives could be achieved through domestic holidays, such as staying in a summerhouse or travelling to neighboring countries instead of more distant destinations. These examples surely need much more elaboration, but we hope that they indicate how this kind of website could be improved to involve users more actively in engaged and informed reflections about the relationships among everyday practices, carbon footprints, and possibilities for behavior change.

Conclusion

This article’s main aim has been to evaluate the extent to which web-based carbon calculators can influence knowledge and meanings that help govern CO₂-producing practices in the everyday life of households and to give recommendations for the design of the next generation of carbon calculators. Even though the empirical material is limited and only includes one specific carbon calculator used in Denmark, our findings have broader relevance, especially as this type of evaluation is rare and the number of carbon calculators is growing. Also, our findings might inspire future studies needed for a better understanding of what role carbon calculators could play in the transition to a low-carbon everyday life.

Our survey results indicate that primarily individuals already interested in sustainable consumption use the website. This is not necessarily undesirable, as this group may need continuous inspiration and reaffirmation to continue being among the “frontrunners” in changing practices. However, website designers should be aware that already knowledgeable users will probably be their main audience for the foreseeable future and acknowledge that various target groups may require different types of information.

Another finding related to the design of the carbon calculator is that it reflects prevalent individualized understandings consistent with notions of political consumption or green consumerism. By deploying this approach, the Map My Climate website failed to open up a more detailed and nuanced discussion of, for instance, the balance between personal and collective responsibility. Without this dimension, the website seems to leave many users with a feeling of victim-blaming or powerlessness, and they simply dismiss the recommendations as irrelevant or too radical. Thus, ecological footprint websites should be designed to encourage or empower users to strive for and act toward collective solutions, for instance through a political process, in part to avoid outright rejection. Our findings suggest that the design of such websites should focus on engaging users in an “active debate” about the relationships between CO₂ emissions and everyday practices and the possibilities and limitations in relation to changing these practices.

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References


Gram-Hanssen & Christensen: Carbon Calculators as a Tool


Article

Industry perspectives on carbon-offset programs in Canada and the United States

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Carbon offsetting is often put forward as a possible mitigation strategy for climate change. This study examines carbon-offset businesses in Canada and the United States to better understand their standards, project types, and project locations and to determine their perspectives regarding the challenges of the carbon-offset industry. Twenty companies (a 40% response rate) agreed to a structured interview, although many were reluctant to share some information. Several salient themes emerged and are discussed in more detail: involvement of the hospitality and tourism industry, financial commitment, confusion in the marketplace, transparency, and needs for education. Implementation of three recommendations—covering standardization, education, and further engagement among the industry, its customers, and researchers—could reduce confusion and increase the transparency of carbon offsetting. Yet these changes might not help business since customers might decide that purchasing carbon offsets does little to address climate change.

KEYWORDS: climaltic change, mitigation, companies, market economy, greenhouse gasses, questionnaires

Introduction: Carbon Offsetting for Climate-Change Mitigation

As human-induced climate change has become a major concern, many techniques have been promoted to mitigate its effects by reducing greenhouse-gas emissions and increasing carbon sinks. One such strategy is carbon offsetting. The World Bank (2008) defines a carbon offset as:

A financial instrument representing a reduction in greenhouse gas emissions…carbon offsets are measured in metric tons of carbon dioxide-equivalent (CO2e). One carbon offset represents the reduction of one metric ton of carbon dioxide, or its equivalent in other greenhouse gases.

Carbon offsets are implemented through activities that are commonly assumed to reduce or absorb greenhouse-gas emissions by, for instance, planting trees, substituting fossil fuels with renewable energy sources, or capturing and storing emissions. In 2008, the volume of the overall voluntary carbon-offset market on project-based transactions was 54 metric tons of CO2e and was valued at US$397 million (Capoor & Ambrosi, 2009).

Concerns about climate change, and the perception that offsets can help, have led to the establishment of hundreds of carbon-offset companies, both for-profit and not-for-profit, around the world. Significant controversies have emerged regarding the effectiveness and ethics of carbon offsetting (e.g., Kollmuss & Bowell, 2007; Broderick, 2008; Gray, 2009; Posner & Weisbach, 2010) and many studies exist of customer attitudes toward carbon offsets (e.g., Becken, 2004; MacKerron et al. 2009; Mair, 2011). However, less attention has been devoted to the vendors of carbon offsets, how they analyze the offsets that they implement, and other perspectives of their work. Butzengeiger (2005), Gössling et al. (2007), and Ribón & Scott (2007) are examples of such studies.

Previous work identifies five main issues with carbon offsetting:

1. Types and locations of projects most pertinent for reducing emissions, including monitoring and verification challenges (Richards & Andersson, 2001; Cacho et al. 2004; van Kooten et al. 2004).

2. Status of standards, which is weak since carbon-offset providers generally follow their own standards for validation and verification, with a low degree of transparency and accountability (Gössling et al. 2007; Kollmuss et al. 2008; Lokey, 2009).
3. Permanence, referring to the “durability of the climate benefit from an offset project” (Carlson et al. 2009; see also Marland et al. 2001).

4. Leakage, defined as carbon emissions in other locations or in the future due to implementing a carbon-offset project (Richards & Andersson, 2001; Auckland et al. 2003).

5. Additionality, meaning that a project that would have happened anyway, without the need for carbon offsetting, should not count (Costa et al. 2000; Richards & Andersson, 2001; Lokey, 2009).

Due to these five issues, considerable skepticism and confusion exist among researchers and purchasers regarding carbon offsetting (e.g., Becken, 2004; Kollmuss & Bowell, 2007). Most carbon offsetting is voluntary, adding to questions regarding effectiveness (Broderick, 2008) because not everyone accepts that giving people a choice in environmental matters will achieve an outcome that ultimately is ecologically beneficial. As well, full disclosure from the carbon-offset companies is often not forthcoming regarding where money is spent and which projects will achieve an outcome that ultimately is ecologically beneficial. As well, full disclosure from the carbon-offset companies is often not forthcoming regarding where money is spent and which projects use which forms of monitoring and verification.

The ethics and effectiveness of carbon offsetting are lampooned to devastating effect by the website Cheat Neutral, which jokingly offers people who have cheated on their romantic partner the option to buy carbon credits to offset their actions (Cheat Neutral, 2008). The point is that it is better not to conduct the offending activity in the first place, whether that offending activity is cheating on one’s romantic partner or using fossil fuels. If one nonetheless insists on doing it, there is an intense moral discussion about whether or not offsetting (the cheating or the carbon) provides some form of compensation.

This article contributes to the literature regarding carbon offsets through research on two objectives: 1) to obtain information from offsetting companies regarding their standards, project types, and project locations and 2) to determine these companies’ perspectives regarding issues and challenges in the carbon-offset industry.

Methodology

To fulfill this study’s objectives, we investigated the carbon-offset market in Canada and the United States. These two countries were understood to constitute the North American market, so Mexico and the Caribbean were not included. Although the market for voluntary offsets was already well-established approximately five years earlier in Europe, it was only around 2004 that it fully took off in North America, with a significant number of small, independent startups (Hamilton et al. 2007; Tansey, 2008). The main reason why uptake in North America has likely been relatively slow is because neither Canada nor the United States has moved forward with legislation that would encourage carbon-offset purchasing, in contrast to the European Union. In North America, venture capital money soon supported companies trying to break into the field (Capoor & Ambrosi, 2007). This development was responsible for the volatile situation of North American carbon-offset businesses at the time of this research in 2009, expressed through the rapid rate of companies being founded, merging, and disbanding.

We compiled a list of all 63 carbon-offset companies active in Canada and the United States at the time. Managers, directors, or owners of these companies were contacted in September–October 2009 via telephone as well as e-mail to complete a structured survey (see Appendix). As per discussion in texts such as Edwards et al. (1997) and Groves (2004), a combination of open-ended and closed questions was developed to glean insight into the business perspective regarding carbon-offset challenges identified in the literature. The survey was based on and expanded from Butzengeiger (2005) and Gössling et al. (2007) and was piloted prior to being used for the full interviews with company representatives.

During the time period of contacting and interviewing companies, the number of firms operating in North America dropped from 63 to 50 due to mergers and closures. Out of the final 50, 23 companies (46%) did not respond and seven (14%) did not wish to participate. In the end, representatives from 20 companies agreed to be interviewed (Table 1), yielding a 40% response rate.

Telephone interviews were used to collect the data (from the method in, for example, de Vaus, 2002; Miller & Salkind, 2002; Leon et al. 2003), except for three e-mail questionnaire responses (respondents #1, #12, and #17, from the method in, for example, Leon et al. 2003) from representatives of companies unable or unwilling to participate via telephone. Each telephone interview lasted approximately 30–45 minutes and was completed with the company’s chief executive officer (CEO), a managing director, or a project manager. CEOs were the preferred interviewees, but at times we were redirected to a managing director or specific project manager, as the CEO deemed such personnel to be more familiar with the answers to the questionnaire. The companies and respondents are kept anonymous here.

Due to the controversies outlined above, some respondents were reluctant to disclose information, so...
not all questions elicited reactions from all of the companies. In some instances, companies had their legal department approve the blank questionnaire before filling it out.

### Findings

**Offsetting Profile of Respondents**

The twenty companies were in business on average for five years. Eight of them were selling offsets for only two years or less while three were selling them for over ten years. Several of the firms had gone through mergers or takeovers, making it difficult to meaningfully establish their exact age. For example, Respondent #6 stated, “Operation since the mid 1990s. The sale of carbon offsets started in 2001—under a different company [name kept confidential here] that merged with [name kept confidential here].”

Thirty-one percent of total carbon-offset revenue for the respondent companies is from individual customers and 69% is from organizations, mainly businesses. Table 2 lists the most prominent industries identified as purchasing carbon offsets—but it represents only a snapshot in time. Respondent #10 highlighted the volatility of the company’s main customers: “Currently it is food service, but if you would have asked me six months ago, it would have been printing; it is continually changing.” Furthermore, Respondent #14 identified no principal industry, explaining that their customers are so broad and varied that they serve many industries nearly equally.

The effects of the financial crisis varied. Eight of the nineteen respondents experienced a decline in sales attributable to the economic downturn. The others said that they were not adversely affected. Of the businesses impaired, a sales decline ranging from 20–50% was reported. According to Respondent #3, “we have seen a 500% increase this year, and have felt no hit from the economic downturn.”

Respondents were asked to describe the types of projects made available to their customers (Table 3) and the most popular projects chosen (Table 4). The count in Table 4 adds up to 22 because two respondents (#5 and #19) noted that their most popular product comprised a combination of two project types that are purchased as a whole product. Respondent #12 explained that project popularity is hard to determine because it depends on customer, price, portfolio mix, geographic location, and type of project. Respondent #5 indicated that s/he does not provide customers with a choice in project type.

### Table 1 List of survey respondents.

<table>
<thead>
<tr>
<th>No.</th>
<th>For profit?</th>
<th>Country</th>
<th>Principal Project Type(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yes</td>
<td>Canada</td>
<td>Biological Sequestration</td>
</tr>
<tr>
<td>2</td>
<td>No</td>
<td>Canada</td>
<td>Biological Sequestration</td>
</tr>
<tr>
<td>3</td>
<td>Yes</td>
<td>USA</td>
<td>Biological Sequestration</td>
</tr>
<tr>
<td>4</td>
<td>No</td>
<td>USA</td>
<td>Biological Sequestration</td>
</tr>
<tr>
<td>5</td>
<td>Yes</td>
<td>USA</td>
<td>Renewable Energy, Methane Capture</td>
</tr>
<tr>
<td>6</td>
<td>Yes</td>
<td>USA</td>
<td>Biological Sequestration</td>
</tr>
<tr>
<td>7</td>
<td>No</td>
<td>USA</td>
<td>Automobile Certificates</td>
</tr>
<tr>
<td>8</td>
<td>No</td>
<td>Canada</td>
<td>Biological Sequestration</td>
</tr>
<tr>
<td>9</td>
<td>Yes</td>
<td>USA</td>
<td>Renewable Energy</td>
</tr>
<tr>
<td>10</td>
<td>Yes</td>
<td>USA</td>
<td>Biological Sequestration</td>
</tr>
<tr>
<td>11</td>
<td>No</td>
<td>USA</td>
<td>Renewable Energy</td>
</tr>
<tr>
<td>12</td>
<td>Yes</td>
<td>Canada &amp; USA</td>
<td>Biological Sequestration</td>
</tr>
<tr>
<td>13</td>
<td>Yes</td>
<td>Canada</td>
<td>Renewable Energy</td>
</tr>
<tr>
<td>14</td>
<td>Yes</td>
<td>USA</td>
<td>Biological Sequestration</td>
</tr>
<tr>
<td>15</td>
<td>Yes</td>
<td>Canada</td>
<td>Renewable Energy</td>
</tr>
<tr>
<td>16</td>
<td>Yes</td>
<td>Canada</td>
<td>Biological Sequestration</td>
</tr>
<tr>
<td>17</td>
<td>No</td>
<td>USA</td>
<td>Energy Efficiency, Biological Sequestration</td>
</tr>
<tr>
<td>18</td>
<td>Yes</td>
<td>Canada</td>
<td>Energy Efficiency</td>
</tr>
<tr>
<td>19</td>
<td>Yes</td>
<td>USA</td>
<td>Renewable Energy</td>
</tr>
<tr>
<td>20</td>
<td>Yes</td>
<td>Canada</td>
<td>Methane Capture</td>
</tr>
</tbody>
</table>

### Table 2 Most prominent industries purchasing carbon offsets.*

<table>
<thead>
<tr>
<th>Industry</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospitality and Tourism</td>
<td>5</td>
</tr>
<tr>
<td>Service Sector (excluding other named sectors)</td>
<td>4</td>
</tr>
<tr>
<td>Energy-Efficiency Services</td>
<td>3</td>
</tr>
<tr>
<td>Venture Capital Firms</td>
<td>1</td>
</tr>
<tr>
<td>Government</td>
<td>1</td>
</tr>
<tr>
<td>Oil and Gas</td>
<td>1</td>
</tr>
</tbody>
</table>

* n = 15 respondents (one answer per respondent)
Barriers to Carbon Offsetting

Biological sequestration projects have the highest risk with regard to permanence. Out of the thirteen respondents offering this option, nine of them had such initiatives as more than 20% of their portfolio and so were asked about permanence (Table 5).

Addressing another problem, when respondents were asked if they believed that barriers existed to customer interest in and support for carbon offsets, four responded negatively. Sixteen respondents agreed that obstacles existed, with some identifying multiple categories (Table 6). Explaining more about carbon offsets—such as how they work, what they do and do not achieve, and the implications of purchasing them—respondents named increasing credibility and sales as a common theme. Respondent #2 stated that “[E]ducation is a must, which includes standards, regulations, and the need for carbon offsetting to be explained properly to gain a full understanding.” Respondent #11 noted that offset companies must “make clear and accurate statements as to what they are doing and how they are doing it,” while also meeting third-party standards.

On the issue of obstacles to interest in and support for carbon offsets, Respondent #4 highlighted the tourism and hospitality industry as facing the most significant barriers. Reasons given were the intangibility of tourism products, the negative opinions and image of offsets, and the reluctance of travel businesses to tell their customers about offsetting because it would draw attention to the negative impacts of traveling. Respondent #6 highlighted these perceptions in the following terms: “There is value in being green, environmentally friendly, or to be perceived as such. However, there is a plethora of ways to achieve this and for many companies this does not involve carbon offsetting.”

Respondents were also asked what recognized standards they adopted to certify their carbon offsets. Two said none, but eighteen answered that they were certified to particular standards (Table 7). No information was provided as to the number of projects certified by each standard that the respondent used. Respondent #8 described how his firm had its own standard, combining already accepted existing standards that were selected. Respondent #6 complained that the existence of so many standards created confusion for the company and its customers.

Standards were the most popular measure for ensuring additionality, but several other techniques were used (Table 8). Respondent #14 used individual project diligence to ensure that the firm’s projects were additional—i.e., project participants monitor for themselves how the activities are undertaken and judge on their own the level of additionality attained—while simultaneously using available standards. Respondent #1 applied its own diverse additionality tests, establishing accurate baseline and performance benchmarks by using what the company stated were best practices along with relevant and available data. This firm also quantitatively demonstrated the additional climate benefits by calculating carbon

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**Table 3** Types of carbon-offset projects offered.*

<table>
<thead>
<tr>
<th>Project Types</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Efficiency</td>
<td>6</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>13</td>
</tr>
<tr>
<td>Industrial gases</td>
<td>1</td>
</tr>
<tr>
<td>Methane Capture</td>
<td>8</td>
</tr>
<tr>
<td>Biological Sequestration</td>
<td>13</td>
</tr>
<tr>
<td>Other (Automobile Certificates/Client Portfolio)</td>
<td>1</td>
</tr>
</tbody>
</table>

*n = 20 respondents (one answer per respondent but two respondents named products combining project types).

**Table 4** Most popular projects chosen by customers.*

<table>
<thead>
<tr>
<th>Project Types</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Efficiency</td>
<td>2</td>
</tr>
<tr>
<td>Renewable Energy</td>
<td>6</td>
</tr>
<tr>
<td>Industrial gases</td>
<td>0</td>
</tr>
<tr>
<td>Methane Capture</td>
<td>2</td>
</tr>
<tr>
<td>Biological Sequestration</td>
<td>10</td>
</tr>
<tr>
<td>Other (Automobile Certificates/Client Portfolio)</td>
<td>2</td>
</tr>
</tbody>
</table>

*n = 20 respondents (multiple answers per respondent).

**Table 5** Methods to address permanence.*

<table>
<thead>
<tr>
<th>Methods</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Third-party validation and verification processes</td>
<td>5</td>
</tr>
<tr>
<td>Risk assessment</td>
<td>4</td>
</tr>
<tr>
<td>Long-term land agreements</td>
<td>3</td>
</tr>
<tr>
<td>Buffer-zone implementation</td>
<td>3</td>
</tr>
<tr>
<td>Project credits are pooled into a reserve</td>
<td>2</td>
</tr>
<tr>
<td>Project location and selection</td>
<td>2</td>
</tr>
<tr>
<td>Tree mortality and survival rate study</td>
<td>1</td>
</tr>
<tr>
<td>Permanence land use</td>
<td>1</td>
</tr>
<tr>
<td>Insurance</td>
<td>1</td>
</tr>
</tbody>
</table>

*n = 9 respondents (multiple answers per respondent).

**Table 6** Barriers to customer buy-in.*

<table>
<thead>
<tr>
<th>Barrier</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of education</td>
<td>8</td>
</tr>
<tr>
<td>Cost</td>
<td>8</td>
</tr>
<tr>
<td>Lack of communication</td>
<td>3</td>
</tr>
<tr>
<td>Legitimacy of carbon offsets</td>
<td>2</td>
</tr>
<tr>
<td>Lack of transparency</td>
<td>2</td>
</tr>
<tr>
<td>Negative customer perception</td>
<td>1</td>
</tr>
<tr>
<td>Lack of government regulation</td>
<td>1</td>
</tr>
</tbody>
</table>

*n = 16 respondents (multiple answers per respondent).
emissions using scenarios with and without the project. In contrast, Respondent #7 did not understand the meaning of additionality or accurate quantification.

Table 9 suggests how carbon-offset companies think that they could reduce customer confusion about why they should purchase carbon offsets, from whom, and which carbon-offset options to select. Respondent #12 noted that the development of standards adopted by all carbon-offset companies, such as the International Carbon Reduction and Offset Alliance (ICROA) in the UK, is a strategy that could contribute to reducing customer (and seller) confusion. That would mean mandatory, rather than voluntary, standards that all companies must obey and be monitored for to be permitted to sell carbon offsets. Respondent #4 echoed this sentiment, noting that carbon-offset companies should be adhering to standards and certifications, along with continuously educating customers on the value and legitimacy of offsetting. Respondent #4 acknowledged that working with other offset providers to ensure that the standards are globally accepted is “crucial” to tackling customer confusion about carbon offsetting.

In discussing “communication” in Table 9, the respondents suggested that their customers needed more information about what carbon offsetting is, the technical aspects of offsetting projects, and the outcomes that result when purchasing offsets. When respondents were asked how they educated their customers about climate change and the need for climate-change policy, including offsetting, the most popular reported method by far was blogs and websites (Table 10). As Respondent #19 stated, “[S]elling offsets is only half of our business; the other half is educating our customers and people on understanding climate change and how to reduce their impact.” Despite the proactive strategies summarized in Table 10, many respondents described relying to some degree on the customer’s predetermined understanding of the issues.

**Table 7 Types of project standard.***

<table>
<thead>
<tr>
<th>Standard Used</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Climate, Community and Biodiversity Alliance (CCB Standard)</td>
<td>5</td>
</tr>
<tr>
<td>Gold Standard</td>
<td>4</td>
</tr>
<tr>
<td>CCX Offset Protocol</td>
<td>2</td>
</tr>
<tr>
<td>Climate Action Reserve</td>
<td>2</td>
</tr>
<tr>
<td>Green-e Energy</td>
<td>2</td>
</tr>
<tr>
<td>The American Carbon Registry</td>
<td>2</td>
</tr>
<tr>
<td>Tree Canada Forest and Urban Tree Protocol</td>
<td>1</td>
</tr>
</tbody>
</table>

* n = 18 respondents (multiple answers per respondent).

**Table 8 Measures to ensure additionality of carbon-offset projects.***

<table>
<thead>
<tr>
<th>Measures to Ensure Additionality</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standards</td>
<td>12</td>
</tr>
<tr>
<td>Third-party verification</td>
<td>8</td>
</tr>
<tr>
<td>Continuous analysis and check-ups on projects</td>
<td>5</td>
</tr>
<tr>
<td>Additionality testing</td>
<td>4</td>
</tr>
<tr>
<td>Review-audit reports</td>
<td>2</td>
</tr>
<tr>
<td>Ensuring partners are additional</td>
<td>1</td>
</tr>
<tr>
<td>Project incentives</td>
<td>1</td>
</tr>
<tr>
<td>Establish performance benchmarks</td>
<td>1</td>
</tr>
<tr>
<td>Clean development additionality tools</td>
<td>1</td>
</tr>
</tbody>
</table>

* n = 18 respondents (multiple answers per respondent).

**Table 9 How to reduce the level of marketplace confusion.***

<table>
<thead>
<tr>
<th>Measure to Reduce Confusion</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication</td>
<td>5</td>
</tr>
<tr>
<td>No greenwashing</td>
<td>1</td>
</tr>
<tr>
<td>Accurate information</td>
<td>7</td>
</tr>
<tr>
<td>Public outreach</td>
<td>2</td>
</tr>
<tr>
<td>Need for regulation</td>
<td>6</td>
</tr>
<tr>
<td>Adhering to standards</td>
<td>9</td>
</tr>
<tr>
<td>Education</td>
<td>8</td>
</tr>
<tr>
<td>Transparency</td>
<td>8</td>
</tr>
</tbody>
</table>

* n = 20 respondents (multiple answers per respondent).

**Table 10 How respondents educate their customers.***

<table>
<thead>
<tr>
<th>Techniques for Communication</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public engagements such as presentations and webinars</td>
<td>4</td>
</tr>
<tr>
<td>Government action</td>
<td>4</td>
</tr>
<tr>
<td>Company publications</td>
<td>6</td>
</tr>
<tr>
<td>Blogs and websites</td>
<td>14</td>
</tr>
<tr>
<td>Calculating and measuring impacts</td>
<td>5</td>
</tr>
<tr>
<td>Using the science of offsetting</td>
<td>2</td>
</tr>
<tr>
<td>Staying current on offsetting protocols and developments</td>
<td>1</td>
</tr>
<tr>
<td>Transparency</td>
<td>8</td>
</tr>
</tbody>
</table>

* n = 20 respondents (multiple answers per respondent).
**Involvement of the Hospitality and Tourism Industry**

In multiple questions, several respondents highlighted the importance of the tourism and hospitality industry for carbon-offset discussions. Furthermore, according to Bows et al. (2009), climate-change mitigation is an essential activity for the tourism and hospitality industry due to its high carbon emissions (see also Gössling & Hall, 2008). Two main sectors of the industry purchase offsets: travel and events/festivals.

The offsets needed for travel are, at the first order, straightforward to calculate by multiplying the distance travelled by the average amount of fossil fuel needed for each kilometer for a given transport mode. Alternatively, companies know how much fossil fuel or electricity each transport mode uses and are able to divide that amount by the number of passengers. Neither method accounts for the full life cycle of the transport mode, which includes such factors as maintaining aircraft or constructing rail tracks, or includes different weights of passengers and their luggage. In addition, they do not directly incorporate specific journey details such as the actual bus or airplane used or any transfers that might be required.

Promoters of events and festivals also face substantial difficulty calculating actual carbon use. For instance, organizers do not usually factor in the carbon emissions from people traveling to participate, although some offer attendees the opportunity to offset all of their own emissions (e.g., Laing & Frost, 2010). Ecneutral (2008) points out that carbon neutrality is increasingly accepted as best practice for events and festivals, leading many respondents to identifying these organizations as important customers. Within the tourism and hospitality industry, respondents identified the cruise sector as taking the least action on carbon emissions. This observation corresponds to earlier research and apparently is still the case, despite the close scrutiny to which the companies in this sector have been subjected in connection with their environmental practices (Brida & Aguirre, 2008).

Another challenge the respondents discussed with respect to tourism was responsibility for carbon offsetting. Is the tourist or the tourism business responsible, and for what aspects of each trip (see also Gössling et al. 2007; Gössling & Hall, 2008)? One example is Backroads, a bike-tour operator, which offsets 100% of the emissions from its support vans, leaving the customer with the option of offsetting the rest of his or her trip (Backroads, 2009). Taiyab (2006) suggests that many tourism companies use carbon offsetting as a tool to “green” their image—the greenwashing that respondents urged against in Table 9. However, the respondents in our study did not delve into whether their tourism customers were using carbon offsets mainly for marketing purposes.

**Financial Commitment**

The respondents identified cost as a major barrier to customers supporting carbon offsets, a factor that might have been influenced by the economic downturn, but it matches Trexler & Kosloff’s (2008) discussion on this topic. Cost is not necessarily easy to calculate. Meta-analyses of cost estimates of carbon-offset projects show that calculations can vary by more than an order of magnitude, depending on the factors considered for the calculation (van Kooten et al. 2004; Manley et al. 2005).

As well, when discussing the tourism and hospitality industry, the respondents indicated that a significant proportion of their customers were small- and medium-sized enterprises that were concerned about any extra costs that they or their customers might incur. Irrespective of whether the interest is there in principle to implement carbon offsets, the financial commitment might sometimes reduce the practical viability of doing so.

**Confusion, Skepticism, and Volatility**

Customer confusion about why they should purchase carbon offsets, from whom, and which options to select was a recurring theme mentioned by the respondents. These insights corroborate findings reported by Dodds et al. (2008) demonstrating that Canadian carbon-offset companies are beginning to realize the extent of the confusion facing their customers. Lack of education, need for regulation, number of standards, voluntariness of the standards, and transparency all contribute to perplexity. Given such challenges, Broderick (2008) questions whether carbon offsetting for tourism could be credible.

The relative youthfulness of the industry likely contributes as well. Companies are still finding their market and exploring how to deal with current and potential customers (Trexler & Kosloff, 2008). Given the frequency of mergers, takeovers, and closures among carbon-offset companies that this study experienced over a short time period, the industry is clearly still working out how to sustain itself. Such a situation is not helpful to customers, since a firm
from which they purchased their holiday offsets in one year might not be around the next year. Meanwhile, customers will not find a single unified industry body or set of guidance standards or regulations to help them select an offsetting company. Instead, there are more than fourteen voluntary standards. Information that customers need to understand the industry and to make offsetting decisions could be better detailed and easier to find and interpret.

The reluctance of many companies to participate in our survey could indicate insecurity in terms of their place in the market or uncertainty regarding their own knowledge. An example is Respondent #7 who did not know the meaning of additionality. As well, some companies noted that they do not often have on staff, or engage with, active scientists. Instead, their information sources, and their perception of their customers’ information sources, tend to focus on reports published by nongovernmental organizations (NGOs) or government bodies. As Respondent #16 described, this information is not necessarily the most objective in terms of project choices, companies for offsets, or overcoming marketplace challenges.

The companies’ confusion—and possibly that of the customers—is compounded by the rapidly changing international scene. As a successor to the Kyoto Protocol continues to be negotiated, provisions might or might not be in place at some point that link carbon-offset projects to binding international treaties. Topics such as clean-energy initiatives and emission-reduction programs from deforestation and forest degradation are part of the international negotiations. As seen with the Kyoto Protocol, signed in December 1997 but not in force until February 2005, even the presence of a ratified, binding international agreement does not necessarily lead to implementation and enforcement. Consequently, carbon-offset companies are working in a vacuum regarding international regulations and options for projects that are legally mandated, monitored, and verified.

The rapid changes in the carbon-offset industry, along with the many sources of confusion, lead to understandable skepticism among customers. The companies selling carbon offsets struggle to overcome this uncertainty and to provide the information needed in a manner that is not so overwhelming as to scare customers away—such as by admitting that, ultimately, reducing consumption is the only way to tackle climate change (e.g., Assadourian, 2010).

**Transparency**

Eight respondents out of twenty suggested transparency in the carbon-offset industry as a measure to reduce customer and seller confusion, yet only two out of sixteen thought that lack of transparency was a barrier to customers purchasing carbon offsets. Action related to improving transparency was not always clear, shown by the reluctance of several respondents to reveal information about their business, thereby reducing the data available for this study.

That reticence might be justifiable from a business perspective, but it is not transparent. For example, transparency would involve revealing the companies’ financial status and giving full information regarding the carbon-offset projects that they support, why those decisions are made, and the advantages and disadvantages of the choices. However, public exposure of these kinds of details could impair business, particularly if some carbon-offset companies were fully transparent and others were not.

One possible approach to transparency would be setting standards, either voluntary or regulated by government. Voluntary standards would likely run into similar problems of contributing to marketplace confusion as detailed above. Government regulations could be opposed by businesses as being unnecessary bureaucracy and potentially giving an advantage to competitors elsewhere, especially if, for example, the regulations were different in Canada and the United States. Transparency could be an insoluble carbon-offset challenge.

**Lack of Education**

At the time of this study, few of the respondents incorporated elements of customer education into their business strategies, even when they were undertaking customer-education actions. The carbon-offset companies also faced two different target audiences: individual and organizational customers. Determining the target audience(s) is further complicated by the organizational customers often passing the onus of purchasing offsets to that organization’s own individual or organizational customers. Consequently, the carbon-offset companies must consider how to get their organizational customers to, in turn, educate their customers.

One example of the challenges emerging when the carbon-offset company faces two different target audiences is dealing with the passenger-airline industry, because the decision to purchase carbon offsets is usually shifted onto an airline’s customers. In December 2010, when reserving a flight with Air Canada, passengers (not the airline) could choose to purchase offsets from the company chosen by Air Canada, Zerofootprint. Then, the customer (not the airline) could choose from among three specific projects: forest restoration in Maple Ridge, British Columbia; landfill-gas recovery in Niagara Falls, Ontario; or tire recycling with a Quebec company. Air Canada gave no explanation for why this particular set of projects was selected. Members of Air Canada’s frequent flyer club, Aeroplan, could also
choose to donate their miles directly to carbon offsetting.

At the same time, the American company United Airlines permitted customers to donate to carbon offsetting separately from booking flights—and even without making a reservation. United Airlines was, at the time of the research, working with Conservation International and Sustainable Travel International on carbon offsetting. Possible programs related to international reforestation, United States-based renewable energy, and international renewable energy and energy efficiency.

Another Canadian airline, WestJet, formerly took a different approach. If visitors entered “Offsetters” (a company’s name) into the promotional code field when booking their flight through the company’s website, WestJet would donate a portion of the price to purchasing carbon offsets. This initiative was not well publicized, so the customer was poorly educated regarding the options. In the booking process of purchasing a WestJet flight, the customer would not be informed that carbon offsets could be purchased, but just had to know what to do. In December 2010, that option was no longer available. The promotional code field would not accept a string as long as “Offsetters” and a search of WestJet’s website for “carbon,” “offset,” and “Offsetters” yielded no results. In December 2010, the company website of Offsetters did not list WestJet as a client.

With these difficulties for just one industry on one continent, the carbon-offset companies do not have an easy task in determining whom to educate and how. With WestJet no longer offering a carbon-offset option and no explanation regarding why, the carbon-offsetting companies have lost a customer. They might not be able to respond to individual customers who wish to use that airline while carbon offsetting, but who also wish to know why their airline does not offer a carbon-offset option.

The marketplace confusion, complications, and lack of education surrounding North American airline-related carbon offsets are mirrored in studies in other locations (e.g., Gössling et al. 2009; Cohen & Higham, 2011; Mair, 2011). The airline industry exemplifies many of the challenges that emerged through interviewing the offsetting companies. Numerous links in the education chain exist, not all of which are transparent, thereby exacerbating confusion among both offsetting companies and customers.

Recommendations and Conclusion

This article contributes to the literature on understanding the perspectives of carbon-offset businesses with respect to challenges and potential changes for addressing identified problems. Barriers to selling carbon offsets include legitimacy of carbon offsets, financial commitment, customer perception, customer education, transparency, lack of communication, and confusing standards. These barriers match what the literature previously suggests as major obstacles (e.g., Gössling et al. 2007; Kollmuss et al. 2008).

Three main recommendations emerge for trying to minimize the overall level of confusion within the carbon-offset market in Canada and the United States: standardization, education, and further engagement among the industry, its customers, and researchers. Each recommendation has advantages and disadvantages for selling carbon offsets, but the questions raised form the basis for a future research agenda.

Standardization

Given that fourteen different standards were used among the eighteen respondents, more harmonization of the rules would encourage increased transparency in, and less marketplace confusion for, the industry. Seeking a common global standard, though, is a daunting prospect and might not be realistic. To achieve that, the wide diversity of governments, businesses, and interest groups involved would need to agree on all the details—an unlikely prospect given differences in accepting how much industry should be regulated and the effectiveness of carbon offsets.

One possibility might be including standards for carbon offsetting in the global climate-change agreement to replace the Kyoto Protocol—if such an accord can ultimately be reached and implemented. Conversely, companies wishing to avoid the international standard could register in locations that do not subscribe to that agreement, conducting their business via the Internet.

No approach to standardization is a panacea. A structure between global standardization and the current situation should be sought to increase transparency and to reduce customer and industry confusion (see also the discussion in Gössling et al. 2007; Kollmuss et al. 2008; Lokey, 2009).

Education

Some carbon-offset companies are already instructing their customers, calling for increased education, and, in some cases, indicating how to do so. In tandem, expanded education for the industry regarding offsetting would be useful to ensure that the firms selling offsets understand and can explain the associated technical issues, such as leakage, permanence, and additionality.

Education on carbon offsets can have advantages and disadvantages (see also Trexler & Kosloff,
2008). The respondents implied that education would improve the industry, especially in terms of convincing more customers to purchase offsets. Simultaneously, transparent education should include all the challenges and limitations with offsetting. That could result in customers concluding that offsets should not be bought because they frequently cannot be monitored, do not address the root cause of the climate-change problem, and are subject to accusations that they cause more harm than good.

From a normative perspective, education of the industry and customers is needed to ameliorate marketplace confusion and to increase transparency. From a business perspective, increased education could reduce business. Balancing different approaches, and understanding their consequences, should be part of a future research agenda.

Further Engagement among Industry, Customers, and Researchers

The respondents provided many useful suggestions regarding improvements for the carbon-offset industry. A literature base is now being built up whereby researchers survey carbon-offset companies or customers to determine their interests, knowledge, and needs. In particular, further exploration should be made regarding how it might be feasible to increase the response rate that informs these studies. While the nonresponding companies might simply not have wished to engage in the survey, the respondents’ comments noted earlier suggest that it was more likely that 1) they did not see the immediate value of the study for themselves or the industry or 2) they could not or would not share information about their clientele because they regarded this information as confidential or proprietary. Future studies could be improved by immediately and directly indicating what the companies would gain from participating, while initially avoiding any clientele questions until rapport has been established. It could then be determined how much information a company would be willing to provide.

Part of this process would be to examine whether or not companies that declined to participate share certain characteristics, thereby skewing the results of those who do respond. Continued work along similar lines (and considering countries other than Canada and the United States) would help to expand this knowledge base while establishing trends to indicate how the industry is evolving and should evolve.

Further information from the companies would also permit a deeper, more verifiable comparison. Many of our respondents declined to provide information on the price per ton of carbon reduced. Within the bounds of ethical research, it might be feasible to try purchasing carbon offsets from companies to obtain a price comparison—at minimum for those firms selling carbon offsets to the public. However, often the price to the consumer masks the real price of the carbon offset; companies typically consider such information confidential. Nonetheless, further research and collaboration with the industry over the long term might yield mechanisms for reporting this information with the companies’ permission.

Whether or not that information is fully useful is an open question, since one of the largest challenges in this field is the rapidity of changes. With so much uncertainty regarding the post-Kyoto Protocol agreement, coupled with the industry’s relative youth and volatility—in terms of companies forming, merging, and disbanding—the industry could use researchers who have longer-term perspectives and data sets to understand how different factors affect demand.

Such analyses offer no guarantee of supporting the need or market for carbon offsets. The carbon-offset industry is not likely to disappear, but it remains unclear whether or not it will contribute meaningfully to climate-change mitigation.

References


Brida, J. & Aguirre, S. 2008 The Impacts of the Cruise Industry on Tourism Destinations. International Congress on Sustainable Tourism as a Factor of Local Development. November 7–9, Monza, Italy.


Appendix: Final Survey Questions

1. How many years have you been selling carbon offsets?

2. Approximately what percentage of your total carbon offsetting sales/revenue are based on individual consumers and what percentage are based on companies?

3. Of the corporate based offset purchases, which industry is the most prominent?

4. What types of carbon offsets do you offer (check all that apply)?
   1. Energy Efficiency
   2. Renewable Energy
   3. Industrial Gases
   4. Methane Capture
   5. Biological Sequestration
   6. Other, please specify

---


5. What is the most popular type of carbon offset purchased through your organization?
   1. Energy Efficiency
   2. Renewable Energy
   3. Industrial Gases
   4. Methane Capture
   5. Biological Sequestration
   6. Other, please specify

6. How many tonnes of CO₂ have been offset by your company in the 2008 fiscal year? What percentage of these have been purchased by hospitality and tourism companies?

7. Have your carbon offsets been certified to a recognized standard (Gold Standard, CDM, VCS, Climate Action Reserve, Green-e Climate Protocol for Renewable Energy, etc.) to ensure quality? If so, please list which standard(s) you abide by.

8. What steps have you taken to ensure that the carbon offsets you are selling are additional?

9. How do you ensure that the greenhouse gas reductions that your carbon offsets represent are quantified accurately?

10. Are 100% of your offsets validated and verified by accredited third parties?

11. What percentage of your portfolio is made up of offsets from tree planting or agricultural soils projects? If it is a significant percentage (more than 20% of your portfolio), how do you address permanence risks?

12. Due to the economic downturn, has your company seen a decline in offset purchases? If yes, by how much (approximately)?

13. How important do you feel carbon offsetting is in mitigating climate change?
   1. Not important
   2. Slightly Important
   3. Neutral
   4. Important
   5. Very Important

14. How can carbon offsetting companies reduce the level of confusion in the marketplace?

15. What are you doing to educate your buyers about climate change and the need for climate change policy?
A new model for enabling innovation in appropriate technology for sustainable development

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The task of providing for basic human necessities such as food, water, shelter, and employment is growing as the world’s population continues to expand amid climate destabilization. One of the greatest challenges to development and innovation is access to relevant knowledge for quick technological dissemination. However, with the rise and application of advanced information technologies there is a great opportunity for knowledge building, community interaction, innovation, and collaboration using various online platforms. This article examines the potential of a novel model to enable innovation for collaborative enterprise, learning, and appropriate technology development on a global scale.

KEYWORDS: innovations, technology transfer, developing countries, databases, experiential education, Intranet

Introduction

In the “Internet Age” more than one billion people continue to live in impoverished conditions inferior to those of the Minoan Civilization (circa 2200 to 1450 BC) (Gates, 2000; UNDP, 2001). For example, the Minoans had a community-water system (Logiadou-Platonos, 1980), yet today ingestion of unsafe water, inadequate availability of water for hygiene, and lack of access to sanitation contribute to approximately 1.5 million child deaths every year (Ezzati et al. 2002; WHO, 2002). Approximately 2.6 billion people currently have no access to a hygienic toilet or latrine (WHO, 2010), while overall 10.8 million children under the age of five die each year from preventable causes (Black et al. 2003). These deaths are largely related to poverty: as of 2004, just under one billion people live on less than US$1.08 a day and 2.5 billion people live on less than US$2.15 a day (Chen & Ravallion, 2007). The enormous challenge to our generation is increasing as the world’s population continues to expand—to an expected nine billion people by 2050 (UNDESA, 2008). How we meet the needs of this growing population in a just and equitable manner within the ecological capacity of the earth is the major challenge of sustainable development.

To address these situations, a variety of government programs, nongovernmental organizations (NGOs) and the United Nations Educational, Scientific and Cultural Organization (UNESCO) have undertaken initiatives to enable technology and information diffusion among communities to support sustainable development. The success of these endeavors requires a systematic approach with coordinated contributions from a wide range of individuals and stakeholders (Limerick et al. 2002; Fiksel, 2006); yet presently, information and communication systems are not sufficiently effective in diffusing technologies among the wide range of audiences. For instance, how can a small business in a developing village in China access the thermodynamics knowledge of a mechanical engineer at an American university? How can the economic sustainability of the community of Gaviotas, Columbia share a simple heat-exchange technology used in Chinese businesses (Weisman, 1998)? How can American communities benefit from the design improvements on solar hot-water heaters made in Gaviotas?

These modes of technology transfer do not presently occur because there is limited and weak communication between developing communities and researchers, resulting in poor technological diffusion and redundant time and resource-consuming research and development for communities of all nations. A
new method of technology transfer and communication among communities is clearly needed on a global scale. This article outlines the necessity and the components for creation of a new research endeavor that would allow for much faster and more efficient diffusion of ideas and technology. Such an enabling innovation (EI) system would be designed to inspire the formulation of sustainable social and technological solutions by facilitating knowledge and technology transfer among communities with the support of educational institutions, NGOs, and industry.

This article describes the core of the system’s design: an online community that would catalyze and disseminate innovation by providing local innovators with multilingual and visual representation of: 1) innovation use by geographical location and resource availability; 2) innovation evolution or adaptation; 3) social networks among innovators; and 4) networks of complimentary innovations or systems designs. The online community would document the evolution of innovation and provide ready access to local innovators, NGOs, and academic resources to support collaborative development of sustainable solutions. Customized community portals would provide relevant information for specific groups of users (e.g., to match their geographic, economic, or otherwise particular circumstances). Moreover, this communication channel would create an opportunity for faculty and students to directly contribute to sustainable development while enhancing their understanding of key traditional topics in education via experience-based service learning.

**Examples of Community-Knowledge Building Using Information and Communication Technologies**

To address the challenge of sustainable development, it is imperative that people in the developing world have access to a broad knowledge base that can significantly improve quality of life (King & Hill, 1993; Gurstein, 2000). This kind of collaborative networking via information and communication technologies (ICT) is on the rise. Some examples of knowledge-sharing networks include those that provide access to weather and marine conditions, crop and product valuation, micro-credit loan and financial tracking, government services and records, healthcare information, transportation services, and maps of Geiger counter readings from the 2011 nuclear disaster in Japan (King & Hill, 1993; Arunachalam, 2002; Cecchini, 2003; Tcheeko & Ntah, 2006; Pearce, 2012a). Organizations such as Science for Humanity, Health Unbound, Grameen Bank, One World Trust, and many more are great examples of the collective work being done for sustainable development through a variety of disciplines and domains. The examples highlighted below relate specifically to the historical field of appropriate technology (AT) or modernized open-source appropriate technologies (OSAT). The concept of OSAT refers to technologies that are designed in the same fashion as free and open-source software. These must be AT, which is defined here as technologies that are easily and economically used from readily available resources by local communities in the developing world. Effective AT must meet the boundary conditions set by environmental, cultural, economic, and educational resource constraints of the local community (Pearce, 2007).

Merely supplying ICT equipment is not an optimal solution (Ashraf et al. 2007). A more nuanced approach to the communication of knowledge is required to leverage ICT to support innovation. Arunachalam (2002) points out that the majority of ICT projects flooding the developing world are doing so in an irresponsible manner and for the primary benefit of hardware and software companies. Because these ICT projects often resulted in failure and restrictions, Hicks (2008) demanded new goals of sustainability, scalability, and evaluation. Arunachalam (2002) called for a more “people-centered” approach so that technology could contribute to participatory development, which can avoid these problems. ICT is merely a tool, while user-driven content and use must be the primary foci to help communities become sustainable. To succeed in other endeavors, teachers and organizers apply the same principle to students (Wasson, 2007) or existing online communities like Wikipedia (Baytiyeh & Pfaffmann, 2010). To achieve this goal, there must be a mechanism for participatory development so that the community is able to play a role in appropriating the technology, and there also must be continuous study of how to improve and evolve the systems to better suit people’s needs. Several successful models for accomplishing this aim with large user communities are reviewed here: the M.S. Swaminathan Foundation, Village Earth and Appropedia, Catalytic Communities, and Service Learning.

**M.S. Swaminathan Foundation**

The M.S. Swaminathan Foundation (MSSF) is an ongoing nonprofit organization founded in 1988 that focuses on economic growth for poor women in rural areas. Operating in India, with funding from Canada’s International Development Research Centre (IDRC) and the Canadian International Development Agency (CIDA), MSSF’s Center for Research on Sustainable Agriculture and Rural Development established a network connecting approximately twenty
rural Indian villages to the Internet. The key premise has been to promote sustainable rural livelihoods through digital empowerment, technology choices, and dissemination, as well as by encouraging human-resource development. The emphasis has been on locally specific, demand-driven content and capacity building through different communication tools.

The MSSF approach begins by asking villagers what information they are most interested in accessing. To gain access to these services, the villagers must provide a public center to house the computer systems and a salary to pay indigenously trained operators. In return, MSSF provides hardware, software, and support. In addition, the Foundation creates a customized community website or portal using the local language that provides quick access to their requested information. Having demonstrated the benefits of such ICT projects for poor rural communities, MSSF launched another project in 2004 involving a national movement to enable up to 600,000 villages throughout India to build similar rural knowledge centers (Shore, 2005).

**Village Earth and Appropedia**

Village Earth, a consortium for sustainable village-based development, exemplifies a participatory approach to development. Village Earth is a nonprofit organization (NPO) based in Colorado that works to achieve sustainable development by connecting communities with global resources through training, consulting, and networking to collaborating organizations worldwide (Bradley & Newberry, 2004).

Village Earth has projects with the Oglala Lakota on the Pine Ridge Indian Reservation in South Dakota, the Shipibo-Konibo of the Amazon region of Peru, and in India, Cambodia, and Guatemala. Village Earth begins by leading communities through a series of workshops in which participants create a common vision, identify obstacles and constraints, and formulate an actionable plan. A Village Earth representative provides a link to outside resources and knowledge through a variety of information sources that have been created within the organization, including a digitized AT library comprising scanned books and documents and a more dynamic and newly evolving AT wiki that has recently merged with Appropedia, a website for collaborative development of solutions focused on sustainability, poverty reduction, and international development (Pearce, 2012b).

Appropedia is a wiki-based website (in other words a website where a large number of participants are allowed to create and modify the content directly from their web browsers). Appropedia has enormous potential to assist in fostering sustainable development because it takes on the administration of collaboratively organizing information, project examples, and best practices and thus allowing organizations committed to sustainability, appropriate technology, social entrepreneurship, service learning, and international development to focus on what they do best. Appropedia has already become the AT venue of choice for organizations such as Engineers Without Borders-Australia and Demotech and is set to expand rapidly as other organizations use its information-transfer capability.

The Appropedia website, combined with recent advances in semantic MediaWiki, allows for annotating semantic data within wiki pages. Data that have been encoded can be used in semantic searches and to aggregate web pages; displayed in formats like maps, calendars, and graphs; and exported to the outside world via various formats. The first example of the application of semantic wiki functionality within Appropedia involved the Global Health Medical Device Compendium (an inventory of medical devices designed for use and/or implemented within resource-limited settings). The compendium can be sorted by *health topic* (e.g., malaria or HIV/AIDS), *classification* (e.g., preventative, diagnostic, or clinical), *scope* (e.g., prototype, clinical trial, or commercialized), and *location* (by continent).

The participatory approach supported by Appropedia and used by Village Earth focuses investment toward assisting local residents to research, design, and innovate within their own community. Village Earth teaches people to access information, but the organization’s representatives do not make recommendations. The villagers own the projects and the decisions. The Village Earth approach focuses on teaching innovation and development processes that assist communities to better themselves. Once the process is in motion, a resource-access unit is created by training a group of local community members to acquire outside knowledge and resources. Once Village Earth has enabled such a connection, the organization is able to move forward to a new community.

**Catalytic Communities**

In Rio de Janeiro, Catalytic Communities (Catcomm) provides a third example for assisting communities with ICT through a participatory approach. Catcomm is a NPO with a mission to develop, inspire, and assist a global network of communities generating and sharing solutions (Badamas, 2005). The organization provides physical and virtual spaces for communities to exchange ideas. Their community centers provide ICT access and foster the congregation of community leaders while their community-solutions database enables people to post their success stories, inspiring others to enhance their own communities. The database provides hundreds of...
examples of successful community solutions throughout the world. It references both social and technical applications, but is primarily built to support social and technological innovations. The community-solutions database was started in 2003, but since 2009 CatComm has been involved in a partnership with WiserEarth, an international civic directory and networking forum that gives community partners access to the knowledge resources of WiserEarth’s 1.5 million users from 243 countries around the world. Since the merger, CatComm’s database-functionality features have been boosted to include member ratings and collaboration tools.

The Catcomm methodology is useful because it details the steps and potential obstacles to creating these social innovations, allowing others to replicate them within their own communities with a decreased need for in situ research or lengthy processes of trial and error (e.g., lessons learned from applications in the field). Just as Appropedia facilitates the construction and testing of enabling artifacts, such as high-efficiency stoves, Catcomm enables the production and adaptation of quality-of-life enhancing social structures (e.g., how to set up a daycare facility), allowing them to be replicated elsewhere with appropriate modifications accounting for differences in culture, resource availability, regulations, and so forth. The partnership between CatComm and WiserEarth, as well as the one involving Village Earth and Appropedia, recognize that when united under common causes and using the networking capacities of online communities their collective impact and outreach can be much greater than if they operated in isolation.

A New Research Thrust

The above examples constitute a new model to facilitate community involvement to reach successful sustainable development that reduces poverty while allowing communities to thrive indefinitely on renewable resources. However, all of these methods, although successful in terms of solving locally focused sustainability problems, are still somewhat limited in scale and only reach a small fraction of the world’s developing communities. The keystone for harnessing this enormous potential is in a reliable method of networking the knowledge of numerous organizations—including institutions of higher education, NPOs/NGOs, and governments—with developing communities. These organizations provide a direct conduit of necessary information between communities in developing countries and research groups that are working on generalizable solutions to technical and social problems. More than a decade ago, Bruce Alberts (1999), a former president of the National Academy of Sciences in the United States, called for

[A] global electronic network that connects scientists to people at all levels—farmers’ organizations and village women, for example. The network will allow them to easily access the scientific and technical knowledge that they need to solve local problems and enhance the quality of their lives, as well as to communicate their own insights and needs back to scientists.

Since this appeal, the need for an OSAT network has not diminished (Zelenika & Pearce, 2011). The EI system, proposed here as a major new research project, is designed to build such a network to allow AT research to reach a much wider range of communities.

Research Design Model—Enabling Innovation

The EI research design model consists of two primary functions: create a system for the exchange of indigenous knowledge and innovation among developing communities and then establish a communication channel to allow communities to solicit support from educational institutions and service organizations. The EI database would provide a hub for knowledge and technology transfer among developing communities, educational institutions, and service organizations. First, the database would offer a space to document the evolution of innovation of OSATs. This would allow people across the globe to learn from and inspire each others’ sustainable solutions. Second, community portals would provide access to the database in a context relevant to specific groups of users. Finally, this communication channel would create an opportunity for faculty and students to directly contribute to sustainable development while enhancing their understanding of key traditional topics.

Community portals would provide a customized interface with access to local resources in addition to the EI database. The layout of the database information and default search parameters would be optimized for particular communities, institutions, or professional associations. For instance, an urban community portal would highlight and favor solutions from similar communities until the user requested to search beyond the default settings. Some communities might want the project story and historical context to be displayed first while other cultures (such as a professional association) might grav-
Catcomm is an example of a community portal that has been optimized for the city of Rio de Janeiro with local community and leadership networks, fundraising resources, and project highlights.

Figure 1 shows the conceptual layout of EI. The upper-left-hand section illustrates that communities in developing regions would submit a need or a revision request to EI through their customized portal, which houses both community (systems) solutions and individual sustainable innovations (technical- and policy-based solutions to specific problems). When the need was established, the request would be sent to university students, who would then develop, test, and refine proposed solutions. The students and faculty would access the EI database through their own portal. Similarly, foreign language students and volunteers would obtain information and completed solutions that need translation in EI through the educational portals; they would then translate the information and upload it back into the EI database. Service organizations and trade associations would also have their own portals, where they could not only upload useful information to assist businesses in their disciplines, but also request solutions from universities or other EI groups to solve identified challenges. Finally, individual communities and villages would have the same ability to provide their real-world tested solutions to the database for translation and technology transfer.

Core EI Database Capabilities

The core building block of EI is a database designed to document, inform, and inspire sustainable solutions to developing community challenges. Relevance and searchability within such a vast network of information is the key constraint of the database design. Thus, the database must support a suite of tools intended to target useful, pertinent information for each desired user. These core capabilities, critical to the success of the EI system, include multilingual support, innovation evolution or revision tracking, innovation review and rating, innovator rating, certification capability, geographical use and resource tracking, and system-design capacity.

Multilingual Support

To make information accessible around the globe, the EI database would need to support numerous languages. Most large collaborative websites and wiki-sites handle multilingualism by spawning a separate and largely independent site for each language (Désilets et al. 2006). Unfortunately, this approach results in redundancy and squanders resources to replicate existing research and development in each language because the content must be researched, tracked, and written for each language. To overcome this challenge, EI would utilize a system similar to that of Catcomm that relies on a network of volunteers (as does Appropedia as well) where foreign language students would translate material developed in one language into multiple languages (ter Horst & Pearce, 2010). As each native language entry was input into the database through a portal, the entry would be delegated out to a network of translators. This method would not only reduce redundant effort, but would also offer potential as a service-learning teaching tool for language classes. An enormous and

\[ \text{Figure 1 Conceptual Layout of Enabling Innovation.} \]
steady amount of valuable work would need to be performed to maintain the EI database considering the fast and ever-changing nature of the development of appropriate technology all over the world. At the same time, translation software is also improving, potentially eradicating language barriers to information. Such automated translation services could serve an important stop-gap role to provide rudimentary details when entries were first input, but computer translations of such material are still notably flawed, necessitating the intervention of human translators.

It should be pointed out here that in addition to spreading information, capturing indigenous knowledge is not limited to language translation. It would, of course, be difficult to build the ontology, structured data tagging, protocols, and systems to ensure quality control for a large variety of topics across a great number of cultures. While the power of collective works should not be undermined, there are limitations to the expertise, continuity, and organization provided by university students and volunteers. For this reason, structure, supervision, and support would also be necessary for the systems to work. Such supervision would ensure that the primary thrust of the project would remain intact, similar to how a core team of experts guides the Linux coding community when changes to the kernel are proposed.

Innovation Evolution or Revision Tracking

Unlike a “best practices” approach that disseminates selected case studies for replication, EI aims to document and inspire creative, local innovation. This does not mean that best practices would be ignored and the figurative wheel would be reinvented in every community, but that communicating the evolution of an innovation is just as essential as disseminating the innovation itself. For instance, a researcher would be able to learn about how a particular community designed a small dam to help resolve desertification problems and to improve local agricultural output. The primary entry would be linked to similar entries portraying how different users in various communities have adapted the dam to work within the environmental, economic, and materials constraints of their particular location. These different adaptations are synonymous to forks in computer coding. Expanding a specific entry would unveil even more adaptations and case studies. This unfolding process would assist the user to innovate—to determine how best to adapt the technology or innovative system for the needs of a particular community. The primary idea or solution would evolve and be optimized for a given context. Communities could use a version applied in a locale most similar to their own.

The comparison of these methodologies would provide another useful research opportunity.

Innovation Review and Rating

Often the investment required to recreate or build an innovation is high. To overcome these developmental costs, first, there must be adequate information and schematics for a user to trust that there is due diligence in a given design and that the designed device can perform to specifications. Second, particularly for small communities with limited access to funding, there must be a successful history of implementation before an investment in time and resources can be justified. Similar to an online store (e.g., Amazon.com), product information, accompanied by successful customer reviews or testimonials, can be useful before purchasing a specific item. EI would need to support a review and rating system for documented innovations. Through user reviews and scoring, successful innovations could be quickly referenced while unproven or unwanted content could be easily avoided by screened sources and display ranking. Similar to Google’s capacity to place the most relevant search string at the top of a list, the most highly ranked innovation to solve a specific problem of a particular device design would be provided to users before less proven designs.

Innovator Rating

To reduce barriers to the diffusion of innovations, new applications from reputable sources could also be prioritized. If an innovation was novel and unproven, but the designer had a long history of successful concepts, a user would be more apt to build off of or invest in the provided information. Furthermore, an innovator-rating system would provide a currency or incentive to encourage participation and quality submissions. Like eBay’s feedback points, experienced innovators could develop a reputation for high-quality technologies. While eBay’s system rates transactions between users, the EI innovator rating would be more product-focused. Buyers would rate the product and the seller’s rating would then be derived from an average of the ratings of the products that they sold. The innovator rating would be based on an average of their innovation ratings adjusted to favor relatively more experienced designers, such that someone with ten five-star innovations would score higher than someone with three five-star innovations. This social capital system is also similar to the impact-factor rating in peer-reviewed literature, where journal articles from publications with high impact factors are presumed to be of better quality. This is an admittedly conservative approach to the diffusion of ideas. It has the benefit of quickly giving credit to innovations from established groups, but has
the disadvantage in lowering the value of work from less established entities. Further work is needed to overcome this limitation.

**Certification System**

An organizational certification system is yet another way to convey trust and overcome barriers to innovation diffusion and information adoption. For example, the forestry sector uses organizational certification to promote sustainable practices by providing trust through a third party that certifies forest products (Rametsteiner & Simula, 2003; Lewandowski & Faaj, 2006). Similar to a *Consumer Reports* stamp of approval, organizations specializing in particular appropriate technologies would be given certification power. This procedure both delegates a certification process and provides organizations with a similar incentive to build, highlight, and market their own set of successful innovations. For example, certain innovations could be certified by the Peace Corps or Engineers Without Borders-Canada. This arrangement would create a currency for organizational participation and allow users who are familiar with or trusting of a specific organization to search through their proven, successful, certified technologies.

**Geographical Use Tracking**

The location of an innovation is often critical to its appropriateness or success. Many renewable energy technologies, such as solar photovoltaic cells, are sustainable solutions in some situations, but have decreased usefulness in areas that are prone to dense cloud cover. In addition, the ability to find innovations that are used locally will allow for a site visit, increase trust, and ease communication with the innovator. All of these factors would reduce barriers to entry or technological adoption. Cross-referencing innovations with sophisticated open-source GIS systems would allow adaptive searching for culturally, ecologically, and economically relevant technologies.

**Resource Tracking**

When documenting an innovation for EI, it is imperative to include the necessary resources, tools, and skills. The database would ideally work like a recipe program, allowing users to input their available resources and responding with solutions that fit their needs. This basic functionality is already seen in Thingiverse, which is a database of physical 3-D objects primarily for applications of 3-D printers. As communities recreate, review, and revise innovations, EI “learns” about their accessibility to resources and helps to autopopulate some of the entries for a given community. The larger the number of communities that utilize the system, the more the database “knows” about the availability of resources, tools, and skills throughout the world and the more adaptive and appropriate the search results can become. Thus, this application increases its value not only with each additional user, but also with each additional use.

**System-Design Capacity**

Many innovations are complimentary or symbiotic while others require a more complex system to succeed. The watershed example mentioned earlier required small dams, terracing, specific agricultural techniques, and an innovative community water-credit system. Any single technology, taken out of context, should not be expected to resolve a problem. Nor could all of the technologies, if transplanted together, necessarily address a similar dilemma in a different context. It is thus important that the user be able to view the innovations as a system. Only then can the appropriate understanding be transferred, assisting other users in meeting their own needs. Similar to Amazon’s suggestive sales techniques, innovations may be highlighted because of their use in conjunction with others. Small businesses that sell a specific water pump, for example, also use a matching wind turbine to drive the pump. In addition, relationships between required supportive technologies can be defined and conveyed to users.

System design applied to businesses or industry is often referred to as industrial ecology or industrial symbiosis. In industrial symbiosis, traditionally separate industries are considered collectively as a system to institute mutually beneficial physical exchanges of materials, energy, water, and/or by-products. The key benefits to using industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity (Chertow, 2000). Successful industrial symbiotic systems have historically evolved as networks of innovations and innovators that collectively optimize material and energy flows at efficiencies beyond those achievable by any individual firm. The leading example is Kalundborg, an industrial city in Denmark, that evolved over a long period of time through incremental partnerships rather than systematically planned or coordinated development (Ehrenfeld & Gertler, 1997). It has been observed that this spontaneous community of industrial symbiosis.
osis emerged because communication and transaction costs were distinctively low since agents were communicating socially. This is difficult and time-consuming to replicate. EI would reduce these informational exchange costs as resource (waste) availability would be part of the database and allow for the design of systems based on industrial symbiosis.

Comparison to Existing Services

Table 1 summarizes the functionality of the EI system compared to the existing information services of MSSF, CatComm, and Appropedia. As is clear from Table 1, EI would provide functionality that is not currently available in any competing/complimentary services for addressing the needs of communities for sustainable development. Overall, the EI system would offer six additional functionalities that currently do not exist in any of the comparable systems 1) innovator rating, 2) innovation rating, 3) formal certification, 4) geographical use tracking, 5) resource tracking, and 6) suggestive searching. Innovator and innovation rating and formal certification could be integrated into Appropedia using existing technology, but have not yet been implemented. Appropedia has enabled Google maps to begin to provide some mapping possibilities, but is far from a fully functional GIS package. Resource tracking and suggestive searching would need substantial developmental work before being implemented in a wiki environment.

### Educational Curriculum Enrichment

The third design component of EI is a set of curriculum-enhancement methodologies to leverage service learning to support sustainable development while educating the next generation in sustainability. Sustainable design and development principles are key foci of higher education at many institutions and service learning is increasingly used to enhance traditional curricula while teaching sustainable design principles (Bryden et al. 2002; Green et al. 2004). However, the field is still in its infancy (Bielefeldt et al. 2005; Sandekian et al. 2005) with much room for development and discussion of pedagogy and methodology to maximize the value of service learning in teaching sustainability. Unfortunately, relatively little work has been done in direct collaboration with developing communities with notable exceptions such as Engineers for a Sustainable World (ESW), Engineers Without Borders (EWB), and the United States Environmental Protection Agency’s P3 (People, Prosperity, and the Planet) programs. On one hand, there are limitations to the impact students can have given their limited knowledge, experience, and commitment to development projects. On the other hand, students’ passion, creativity, and desire to make a difference can be substantial (Komives et al. 1998; Westheimer & Kahne, 2004). While the type and scale of projects would depend on a given group of students, creating a direct communication link among students, educators, businesses, and community members presents an opportunity for service learning to have a potentially enormous impact.
Service Learning

EI provides an opportunity for students to directly contribute to sustainable development in a streamlined fashion. Generally, the most successful university service-learning projects involve students directly with businesses or community groups to address specific problems. These projects usually entail large investments in both time and financial resources for the students to travel and collaborate with local residents involved in the service opportunity, such as the work of Engineers Without Borders (Wing et al. 2007). This type of program can be excellent but prohibitive because of resource constraints for most educational institutions and most universities that do not have on-site service-learning programs.

Creation of the EI database would allow students to work on, research, and solve real-world problems while at their home institutions with no additional financial outlay. This model would also allow developing communities to take advantage of service learning and university research and development, while at the same time harnessing the service-learning motivational advantages for enhancing student learning (Pearce, 2007; 2009). The EI database would enable nearly all of the disciplines to integrate service learning into their curricula. For example, all the science and engineering fields could work on developing and testing OSATs for basic science or engineering labs; mechanical engineers could develop computer-aided design (CAD) files for OSAT projects; the language programs could use EI to provide content for students to proofread, copyedit, and translate; geography students could help identify areas with a competitive advantage for specific innovations; business, accounting, finance, advertising, and marketing majors could assist businesses in formulating successful business and marketing plans; and education majors could develop curricula about individual innovations for accelerating technological diffusion to developing communities.

The vast majority of academic programs could thus implement such “service learning lite” assignments into the curriculum to have students working to solve real-world problems of sustainable development and upload their projects for wider benefit. The motivational aspect of such efforts should not be underestimated. For many students who have never had the opportunity to travel abroad (or even those who have done so), to have their work translated into multiple languages, used by communities all over the world, and receive feedback and international ratings could be extremely gratifying and motivating. The EI project could provide this incentive by encouraging enhanced education through service learning.

Educational institutions have the potential to provide an immense set of resources for fostering AT in developing communities, but there are significant barriers to its adoption (Zelenika & Pearce, 2011). The Massachusetts Institute of Technology, the California Institute of Technology, and the University of Michigan, for example, all feature courses dedicated to developing sustainable AT within a context of engineering or science curricula. Sustainable development AT research, however, is far from ubiquitous. Although some limited work has been done on a number of ATs, the diffusion of these innovations has greatly lagged behind the demand by communities in the developing world, as witnessed by the slow rate of technological diffusion. Service learning is a method to integrate AT research, development, and diffusion into the university curriculum.

Service-learning projects generally provide sophisticated design challenges within a specific set of constraints and they have proved useful as educational tools because when engaged in service learning, students are more motivated, work harder, learn more, and are left with lasting benefits (Cohen & Kinsey, 1994; Giles & Eyler, 1994; Astin & Sax, 1999; Pearce, 2001; Gallini & Moely, 2003; Pearce & Russill, 2003; 2005; Keen & Hall, 2008). Most importantly, the AT projects are so highly engaging and motivational that some universities use them strictly to enhance the educational experience, with little or no method to disseminate the acquired innovations (Pearce, 2007; 2009). The service-learning approach represents a vast (and largely untapped) resource for accelerating sustainable development while enhancing course-based learning.

Challenges

The development of EI represents an amalgamation of many challenges, not all of which are technical (Pearce & Mushtaq, 2009; Zelenika & Pearce, 2011). As Wasson (2007) explains, while there may be no recipe for successful database formation and learning enrichment, given the potentials of collaborative networked scenarios, even the challenges are exciting. It is assumed that the technological challenges of coding the database itself are solvable with an adequate supply of funding and time. Perhaps the greatest inclusive challenge to the EI system is the wide spectrum of target audiences; creating a tool that is concurrently used by faculty at MIT, a business in Switzerland, and remote villagers in the Yu-
cет the system must be compatible to support local and community ownership and participation. Existing models include 1) OpenMRS, a community-developed, open-source enterprise for electronically managing medical records; 2) Coded in Country, an initiative to locally train and support programmers and entrepreneurs in developing regions working on projects that directly affect their own countries; and 3) the social innovations developed and shared by communities at Catcomm.

In addition, this approach can also build communication networks that are in line with or on top of communication systems already in use by various departments and organizations (e.g., existing structures that librarians use, or between field offices and ministry departments). This would make the enterprise easier to sustain over time because of existing support and has the additional benefit of providing a mechanism for secondary communication to grow out of already high-priority communication channels. Having international organizations, which already require multinational or multiorganizational forms of communication, the platform could provide another important mechanism to both scale quickly and maintain sustainability in the long term. Such compatibility and continuity would ensure higher efficiency, influence, and impact. Separate evaluation schemes would need to be designed to evaluate the usability and utility from each user’s perspective. However, the three main challenges to be discussed here are usability and searchability, economic sustainability and intellectual property, and safety.

Usability and Searchability
The EI database is a system for exchanging knowledge and its success is dependent on its ability to support streamlined collaborative exchanges among users. Project-work flows can be observed and studied. The results can then be used to optimize the communication system. Searchability is another primary challenge and will heavily influence content utility to users. The content must be in a format that is the most conducive to learning and users must also be able to identify economically, environmentally, and culturally viable innovations for use in their specific contexts. As such, there is plenty of research demand on how to provide efficient learning services to best support people’s needs and ways to incorporate them within the technological capacity (Huang et al. 2010). As database content grows, search algorithms should be refined to produce the highest quality and most pertinent results.

Economic Sustainability and Intellectual Property
The long-term viability of EI would also depend on its ability to generate direct revenue streams. The project could initially launch through contributions, but could evolve to be self-supportive. In the quest to make the EI venture profitable, extreme care would need to be taken to ensure that the open system is not compromised, nor the integrity of the innovations. This challenge can be partially addressed by the open-source models used by Appropedia and advocated by the Open Sustainability Network (i.e., the text is licensed to the public under the GNU Free Documentation License) (Pearce et al. 2008; Buitenhuiss et al. 2010; Pearce, 2012b). Companies could upload their product designs, enabling anyone to construct them, yet they could also offer links to their own sites for selling the professionally finished product. Intellectual property law would thus quickly become a primary concern for EI. New licensing systems would likely need to be established and open-source software-licensing models might have to be adapted for free and open-source hardware.

Safety
Just as any other technology or information system can be corrupted, the EI system is vulnerable to unethical acts. Mechanisms would need to be created to prevent EI from facilitating harmful innovations such as weaponry, foreseen hazards, poisonous systems, or other forms of violence and terrorism. Reporting systems would have to be implemented to deter, discover, and disable harmful innovations. These are not as serious as they may seem: Wikipedia and Appropedia are vandalized on a daily basis, but given the ease of notifications and the ability to “revert changes” instantaneously, such attacks are largely inconsequential.

Conclusions
This article has outlined a new research endeavor to create an electronic database to inspire sustainable technological solutions by facilitating knowledge and technology transfer among communities with the support of educational institutions and NGOs. EI would enable communities to assist each other to create sustainable solutions that could significantly improve their quality of life. To this end, such a tool could play a significant role in alleviating poverty.

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reducing disease, improving public health, growing local economies, generating ecologically sustainable enterprise, and establishing social and political justice and stability.

Although the variety of government programs and NGOs is growing to enable innovation and information diffusion among developing communities, clearly the EI concept represents a new trajectory for research and development policy. This article describes a means of systematic global communication among communities and provides an opportunity to rapidly accelerate technological diffusion, reduce redundant research and development, and speed economic growth for communities of all nations but particularly for developing countries. Work is currently underway to develop the needed technology for the EI database, while in parallel, Appropedia is being upgraded with functionalities discussed here and continues to collect and distribute OSAT in wiki form.

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ARTICLE

Sustainability of natural movement activity

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In recent years, there has been a focus on reducing energy consumption in commercial buildings as a means of increasing their sustainability. As part of this trend, various health clubs and fitness centers have been designed to lower consumption of resources such as electricity and water. However, energy consumption is just one part of sustainability, with human health and economic health also paramount. When all components of sustainability are analyzed, other forms of physical activity may possess higher levels of sustainability than traditional gym exercise. Natural movement activity consists of outdoor activity that replicates movements performed by ancient humans during the Paleolithic era. A full analysis of sustainability shows that natural movement activity consumes fewer resources and provides unique psychological and physical benefits compared with traditional indoor exercise.

KEYWORDS: physical activity, fitness, environmental impact, economic factors, quality of life, health

Introduction

In efforts to increase sustainability, various commercial gyms and fitness centers have been redesigned or constructed to lower energy consumption. Such improvements include increased natural light, low-flow toilets, and more efficient lighting (Bogar, 2008; Bloyd, 2010). In the United States, a growing number of fitness centers have also in recent years achieved certification under the program of Leadership in Energy and Environmental Design (LEED). To further reduce energy consumption, studies have proposed, for instance, harnessing the power of treadmills or other exercise machines used by patrons to generate power for the building itself (Haji et al. 2010). In the future, it may be possible for gyms to become “net-zero” facilities or actually become net positive generators of energy.

While such efforts are to be commended, energy consumption is only one aspect of sustainability. The United States Department of Health and Human Services (USDHHS) refers to sustainability in terms of the “triple bottom line—human health, environmental health and economic health” (USDHHS, 2011). Commercial gyms, fitness centers, and other physical activity facilities should be analyzed with regard to all components of sustainability. In general, different models of physical activity have different impacts on human and environmental health.

The sustainability of different exercise models becomes more important as public health organizations continue to encourage more physical activity within populations. For example, the World Health Organization (WHO) calls for certain levels of activity based on age, but also emphasizes how additional physical movement can further reduce health risks (WHO, 2010). Curiously, there is no mention of where this activity should occur, nor is there any specific discussion of outdoor or indoor exercise, even though engaging in physical movement is influenced by accessibility of facilities, opportunities to participate, weather, safety, and aesthetic attributes (Humpel et al. 2002). Both outdoor and indoor facilities promote physical activity, as the number of gyms and parks per capita is associated with greater exercise participation (McInnes & Shinogle, 2009). Subjects perceive different benefits and costs to outdoor and indoor exercise, which lead to individual preferences for exercise settings (Huber et al. 2009).

This article seeks to reframe the sustainability of exercise by looking at physical activity from a natural perspective. By focusing on all aspects of sustainability, the possibilities for how and where to engage in bodily exercise can be widened beyond traditional ideas. Other models of physical activity besides traditional gym exercise may both reduce energy consumption and increase health outcomes.

Natural Movement Activity

The last few decades have seen strong growth in fitness center memberships in the United States (Stern, 2011). In particular, commercial gyms have become highly competitive and are popular places for recreational exercise. In 2010, there were approximately 50.2 million gym memberships in the United States (IHRSA, 2011). These facilities offer an in-
door environment with various machines and other manufactured equipment for exercise.

In contrast, a growing area in the health and fitness sector focuses on natural movement, which seeks to replicate physical movements that were necessary for survival in the ancestral world (Cordain et al. 1998; Eaton & Eaton, 2003; O’Keefe et al. 2011). Humans evolved as hunter-gatherers during the Paleolithic era between 2.6 million and 100,000 years ago. During this time, a variety of physical movements were performed on a regular basis, such as walking, running, jumping, climbing, and lifting natural objects (O’Keefe et al. 2011). Early humans did not “exercise,” but rather engaged in daily activity to secure food and shelter. As such, humans are genetically programmed to expect physical activity, and healthy gene expression depends upon it (Booth et al. 2000).

The human genome is primarily the same as it was during the Paleolithic era, yet the pattern of activity in modern life is remarkably different (Cordain et al. 1998). Studies of existing hunter-gatherers show them to be largely free of degenerative disease (Eaton et al. 1988; Carrera-Bastos et al. 2011). Proponents of evolutionary health promotion argue that these hunter-gatherer activity patterns are optimal given our genetic heritage (Eaton et al. 2002).

The modern challenge, some exercise physiologists argue, is, then, to recreate these ancestral movement patterns (Booth et al. 2000; O’Keefe et al. 2011). However, in contrast to modern gym exercise, hunter-gatherer activity had one universal characteristic: it took place entirely outdoors. Outdoor versus indoor exercise requires different environmental resources and may have different impacts on health. For example, a person could engage in running on a treadmill indoors compared to running on an outdoor trail. These two activities require different levels of physical resources and may affect health in different ways. Therefore, the overall human, environmental, and economic sustainability of these two modes of exercise may not be the same.

Prescriptions have recently been offered on how to recreate the physical activity patterns of hunter-gatherers (O’Keefe et al. 2010). For purposes of this article, natural movement activity is based on a relatively strict definition of recreating ancestral movement patterns. This entails that all the major elements of hunter-gatherer activity—taking place outdoors on natural surfaces, going barefoot or in minimal shoes, using natural objects—are needed to classify activity as natural movement activity. In reality, a continuum exists between natural movement activity and gym exercise. However, this article treats them as separate entities for clearer conceptual analysis. For example, could not natural movement be simulated indoors?

Yes, but then the participant would miss out on sunlight exposure, psychological benefits from interacting with nature, and other benefits of outdoor activity. Therefore, the two models of activity are kept distinct for this analysis.

Given their potential differences, it is of interest to compare the sustainability of traditional gym exercise to natural movement activity. To show tangible differences, components of sustainability are compared for a traditional fitness center and an area for natural movement activity. This comparison is not site-specific; it contrasts the general features of a traditional gym to a natural movement area. A customary fitness center is assumed to be housed in a typical building with aerobic and resistance machines, along with other manufactured equipment. A natural movement area would be entirely outdoors. A likely scenario would be a park or nature area that possessed dirt trails for walking and running. Another scenario would be if a private property had a large yard, or if a property were located in a rural area with adjacent open space. The area might also possess other natural objects, such as stones or logs for resistance training.

This article compares the two models of physical activity in regard to the three broad categories of sustainability: environmental health, human health, and economic health. Selected subcategories, where there are significant differences between the two modes of activity, are assessed.

Environmental Health

Energy Consumption

Traditional gyms or fitness centers, similar to any modern building, consume resources such as water and electricity. Efforts have been made to reduce consumption through improvements in construction and design, such as the use of low-flow toilets and energy-efficient lighting. However, modern facilities still consume substantial amounts of electricity, natural gas, and water. For example, in 2003 the average healthcare building used 22.9 kilowatt-hours (kWh) of electricity and 92.5 cubic feet (cf) of natural gas per square foot (USEIA, 2006). In 2000, the average healthcare/medical building used 1,236 gallons of water per day (USDOE, 2010).

In contrast, natural movement takes place outdoors, eliminating the need for the construction of a physical structure and its associated energy consumption. The energy savings can obviously be significant. Outdoor areas avoid these energy costs in both the present and in perpetuity. There may be minimal energy costs for some outdoor areas, such as
electric lighting, mowing, and parking, depending on the specific set up.

Additional energy consumption may be involved in motorized transportation to an exercise site. For this item, it is difficult to determine whether there are significant differences in distances to commercial gyms or to nature areas/parks. This depends on specific geographical areas, and as such, the potential net difference in transport time would require further study.

**Construction Materials**

Commercial gyms require various raw materials for construction. As mentioned earlier, there have been improvements in construction efficiency with the rising influence of “green” construction certification, such as LEED in the United States and the Building Research Establishment Environmental Assessment Method (BREEAM) in the UK. Research shows that for a typical LEED academic building, new construction will range anywhere between US$200 and US$400 per square foot (Matthiessen & Morris, 2004). Based on a previous estimate that an average fitness center is 32,402 square feet, this would result in construction for a new building costing from US$6.8 to US$12.9 million (IHRSA, 2001).

A natural movement area may require some construction materials initially in regard to the trails. Drainage systems may be needed to keep the trails open for use. It is estimated that each mile of trail construction will cost approximately US$50,000 to US$70,000 to create a natural surface trail (Flink et al. 2001). Therefore, to create a typical three-mile native trail, construction costs would range from US$150,000 to US$210,000. Costs may increase with maintenance and upkeep, but may be close to zero for exercise in undeveloped or wilderness areas.

**Human Health**

**Cognitive Benefits**

In general, acute exercise improves mood (Bartholomew et al. 2005; Tsang 2011; Hopkins et al. 2012). Even traditional indoor exercise, such as aerobic or resistance training, has been shown to enhance one’s frame of mind (Hoffman & Hoffman, 2008; Herring & O’Connor, 2009). Over the long term, regular exercise improves mood as well (Puetz et al. 2006).

Though any type of physical activity typically enhances dispositional status, the outdoor aspect of natural movement activity may have unique impacts on the affective state. This is effectively predicted by the biophilia hypothesis that suggests humans gain more satisfaction by viewing natural landscapes (Wilson, 1984). For example, a recent study comparing brief walks in an outdoor versus an indoor environment finds that the former leads to greater enjoyment and also a stronger intention to engage in future activity (Focht, 2009). A recent systematic review highlights that outdoor exercise produced greater increases in relaxation and revitalization along with greater decreases in anger and depression when compared to indoor exercise (Thompson et al. 2011). Another analysis finds that the unique benefits of outdoor exercise appear within as few as five minutes spent outdoors (Barton & Pretty, 2010). The outdoor setting for natural movement activity lends itself to other unique mental benefits. In addition to mood enhancement, studies have shown how interacting with nature leads to increases in cognitive functioning (Kaplan, 1995; Bratman et al. 2012). Experiments have demonstrated that walking in nature or viewing nature scenes reduces stimulation and restores attention-focusing abilities (Berman et al. 2008). An intervention study found that environmental interaction can lead to a quicker recovery of cognitive skills in women treated for breast cancer (Cimprich & Ronis, 2003). Further, a parental survey demonstrated that for children with Attention Deficit Disorder (ADD), time spent in “green” spaces decreases symptoms (Kuo & Taylor, 2004).

**Exercise Adherence**

Activity must be adhered to over the long term to continue to produce health benefits. One of the primary positive outcomes of indoor exercise is potentially greater comfort due to protection from the elements. Personal safety issues perhaps play a part, as may be surmised from a recent study of African-American women showing that indoor walking facilities lead to greater exercise adherence than exercise in neighborhoods or outdoor spaces, though the relationship is unclear (Zenk et al. 2009; see also Kerr et al. 2008). However, another investigation compares the restorative effects of outdoor versus indoor exercise (Hug et al. 2009). Outdoor exercise was found to lead to greater restoration of attention, and restoration predicts the frequency of exercise during the prior thirty days.

A meta-analysis shows that accessibility and opportunities are important determinants of adults’ participation in physical activity, but weather has surprisingly been shown to be a weaker factor of exercise participation (Humpel et al. 2002). Along the same lines, a recent survey shows perceived benefits and disadvantages to both outdoor and indoor exercise, demonstrating that either model can be attractive depending on the individual (Huber et al. 2009).
Foot Musculature

Indoor exercise typically takes place on flat, human-made surfaces such as tile or hardwood floors. In modern gyms, participants often exercise on treadmills, which consist of a hard, flat rubberized surface. These arrangements represent a departure from the outdoor surfaces on which ancient humans traveled. Hunter-gatherers walked on natural, uneven terrain through tropical grasslands (Marean, 1997). Natural surfaces may be superior to typical modern surfaces in terms of physical health in two ways. First, surfaces such as grass or dirt are softer than indoor surfaces, and reduce loading of the joints (O’Keefe et al. 2011). Second, natural surfaces have undulation, and walking on uneven surfaces improves balance and physical function in adults (Li et al. 2005). Through these two mechanisms, performing exercise on natural surfaces can lead to improved health outcomes.

A related aspect to the surface issue is footwear. Indoor fitness centers often require athletic footwear, while there is no such mandated requirement at parks or in outdoor environments. Hunter-gatherers generally went barefoot or perhaps wore minimal shoes (O’Keefe et al. 2011). This situation is in contrast to the heavily cushioned shoes often used during indoor athletic activity. Recent research has shown that barefoot locomotion is more efficient, both on a treadmill and overground, than shod locomotion (Hanson et al. 2011). Use of heavily cushioned shoes lessens the sensory feedback to the feet and may contribute to higher injury rates due to improper body positioning (Robbins & Hanna, 1987). Other investigations have shown that predominantly barefoot populations have very few of the orthopedic problems prevalent in Western society (Engle & Morton, 1931; Schulman 1949; D’Aout et al. 2009).

Nonetheless, the overall benefits of barefoot locomotion are still controversial. Recent studies show that shod running generally increases impact forces to the body, but Western adults who have grown up shod have different barefoot running mechanics than those who grew up barefoot (Lieberman et al. 2010). An overall review of the literature shows barefoot running as a viable source of activity, though one that may require additional training (Jenkins & Cauthon, 2011).

Vitamin D Levels and Sunlight Exposure

Traditional gym exercise usually takes place indoors, limiting access to sunlight. The outdoor aspect of natural movement activity leads to a unique potential benefit via sunlight: increased vitamin D levels. Currently, 41.6% of the American adult population is considered vitamin D deficient due to indoor living and reduced sunlight availability at higher latitudes (Forrest & Stuhldreher, 2011). Low vitamin D levels are associated with a large number of adverse health conditions, such as cancer, cardiovascular disease, and type-2 diabetes (Garland et al. 2011; Holick, 2011). Short amounts of time spent in the sunlight, depending on season and latitude, can improve vitamin D status (Webb et al. 2011). While vitamin D levels can be increased through both food and supplementation, they can also be increased at no cost by spending sufficient time outdoors. A recent study showed that outdoor exercise reduced the risk of hypovitaminosis D in the obese (Florez et al. 2007).

In contrast, overexposure to sunlight has a well-known link to skin cancer, especially for children (Armstrong, 2004; Moehrle, 2008; Green et al. 2011). The depletion of the stratospheric ozone layer, along with climate change, may also increase the risk of certain cancers (Norval et al. 2011). Indoor exercise provides a clear protective measure against excessive ultraviolet (UV) radiation and is beneficial in this regard. The challenge for exercise models is to provide the benefits of moderate sunlight exposure while protecting against the harmful effects of excessive UV radiation (Holick, 2008).

Economic Health

The role of economic health in sustainability usually relates to employment and economic diversification. Commercial gyms are a source of jobs and can add to an area’s economic diversity. Natural movement activity taking place in parks or nature areas would typically be funded by government agencies or nonprofit groups. These agencies may also create employment (through, for example, park maintenance) that could contribute to economic diversity. Whether one model of physical activity produces more economic benefits is unclear.

However, there is a significant literature linking health and work productivity (see, e.g., Schultz et al. 2009; Van den Heuvel et al. 2010; Zhang et al. 2010). If one form of activity can produce more health benefits, this may lead to additional economic health via higher productivity. Employers face economic loss for direct healthcare costs, but even greater costs due to the associated loss in productivity (Loeppke et al. 2009). Therefore, the health effects of different physical activity models should be included in the discussion of economic health.

Open space such as parks may also produce additional economic benefits. Homes near parks generally have relatively higher property values, which can lead to increased tax revenue for local governments (Bolitzer & Netusil, 2000; Lutzenhiser & Noelwahr, 2001). Open space, as compared to residential devel-
Development, also tends to have a positive overall impact on municipal budgets (Kotchen & Schulte, 2009).

Discussion

The evidence presented here shows that natural movement activity is likely to have, on balance, positive effects on human health combined with relatively low consumption of environmental resources. In terms of economic, environmental, and human health, natural movement activity appears to be a highly sustainable form of physical activity. Shifting the proportion of exercise time toward natural movement activity could increase overall sustainability. Directing participants who are new or returning to exercise toward natural movement could also increase overall sustainability. Such a shift would require awareness, leadership, and education about the benefits of this type of physical activity.

The possibility of this shift toward natural movement raises several questions. The first concerns sufficient access to natural environments, which, in urban settings, may be limited to parks. A study of Canadian children demonstrated that those with greater access to parks reported greater physical activity (Veugelers et al. 2008). A second question concerns climate. It has been previously shown that season/time of year affects levels of recreational physical activity (Burton et al. 2003). Therefore, natural movement activity may be less appealing in certain climates or seasons. Third is the issue of inclement weather, such as rain or snow, and how that may hinder motivation to engage in natural movement outdoors (Nies & Motyka, 2006). Finally, there is the potential for overexposure to sunlight and its associated risks, although these could be lessened through simple measures such as sunscreen and education.

Another issue is social support, one of the keys to behavior change, particularly since people generally prefer exercising in a social setting (Nies & Motyka, 2006; Greaves et al. 2011). Recent research indicates that outdoor exercise is as effective as social support in terms of exercise adherence, and the combination of the two may be superior (Barton et al. 2012). Therefore, group-based programs for natural movement activity may be more successful in facilitating change than merely encouraging individual exploration.

Changing activity preferences throughout the lifecycle is also an important consideration. There is evidence that the level of formal gym exercise, such as aerobics, may decrease with age (Bélanger et al. 2011). Whether general preferences for outdoor versus indoor exercise change with age is a question that to date has not received adequate research attention.

The applicability of natural movement exercise to all age groups merits further investigation.

Conclusion

This article analyzes the sustainability of different models of physical activity. Compared to traditional gym environments, natural movement activity consumes fewer resources such as water and electricity. Natural movement activity also produces increases in psychological health greater than traditional gym exercise. However, traditional gym exercise provides protection from the elements that may improve adherence.

Taken in sum, natural movement activity exhibits a high overall degree of sustainability and should be undertaken by responsible organizations. By engaging in more sustainable patterns of physical activity, society can reduce resource consumption and improve health outcomes.

References


EDITOR’S NOTE

Policy debate: editorial introduction

National governments are due to convene in Rio de Janeiro on June 20–22, the twentieth anniversary of the 1992 Earth Summit, to affirm their commitments to sustainable development. However, by virtually any measure, progress toward a more sustainable future has been halting. In fact, many indicators—most notably greenhouse-gas emissions—suggest that as a global community we have actually taken several steps backwards during the intervening years. Regardless of how one interprets the past two decades, there is little question that opportunities have been squandered and precious time has been lost.

The United States surely plays a critical role in the international politics of sustainability and its activities during the final lead-up to the Rio conference, and indeed at the event itself, will be critical to how the challenges are framed. While the following article by Alan Hecht and his colleagues should not be interpreted as constituting an “official” policy position, it merits careful review because of the instructive insight that it provides on the views of several authors who, over the past twenty years, have played key roles in shaping the discourse on sustainability at the highest levels of government.

This Policy Debate also includes a response from John Stutz and I am grateful that he accepted my invitation to contribute to this discussion. The exchange concludes with a rejoinder by Alan Hecht and his colleagues.

The issues raised here demand thoughtful consideration during the final stages of the preparatory process for the Rio event as well as after all the conference have returned home. Accordingly, SSPP has created a forum in which readers are encouraged to contribute to the conversation. We welcome your comments and reactions. Just click on the comments tab to join the discussion.

Maurie J. Cohen
Editor
POLICY DEBATE

Creating the future we want

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Although the world faces serious environmental, economic, and social challenges, we believe that a combination of science and innovation, effective governance, and public-private collaboration can help to overcome many of them and achieve sustainable development. Numerous government policies are now promoting sustainable management practices, while many people in the business and financial communities view sustainability as a means to reduce long-term risk, enhance competitiveness, and promote social well-being. Advances in science and technology are creating new economic opportunities and producing sustainable solutions, while expanded public access to global data and information is helping to shape business and government policies. Looking ahead, sustainability will be best pursued by building on these trends and encouraging new collaborative initiatives among governments, businesses, and the nonprofit sector. This article is an example of a collaboration that includes government, business, academic, nongovernmental, and international organizations.

KEYWORDS: international policy, sustainable development, social responsibility, economic conditions, environmental protection, business, industry

Introduction

In June 2012, corporate, nongovernmental (NGO), and government leaders will converge in Rio de Janeiro, Brazil for a conference on sustainable development. Occurring twenty years after the first Rio conference, the “Earth Summit,” the 2012 meeting is a chance to examine and reaffirm commitments to global sustainability.

As articulated by the United Nations Industrial Development Organization (UNIDO), the meeting provides a timely opportunity to ensure a “shared and common understanding of [sustainability] and what it means to improve the lives of ordinary people in developing countries and countries with economies in transition” (UNIDO, 2011). The title of the initial draft of the conference outcome document, “The Future We Want,” is the inspiration for the title of this article (UNCSD, 2011).

Over the next two decades, governments and businesses will face serious environmental and social changes that hold both risks and opportunities (KPMG, 2012). We are optimistic that we have the capacity to meet these challenges and achieve a strong global economy while advancing social well-being and protecting human health and the environment.

Several trends inspire our hopefulness: leaders in corporations and financial institutions are moving toward sustainable operations and globally responsible investing; advances in science, technology, innovation, and social marketing via the Internet are creating new economic opportunities for sustainability; and national, state, and local governments around the world are taking leadership roles in pursuing sustainability.

Some commentators are less optimistic about the future. As The Economist (2011) observed in a recent review of the planet’s growing population and its
potential impacts, “Once upon a time, the passing of population milestones might have been a cause of celebration. Now it gives rise to jeremiads” (emphasis in original). Population growth, along with increasing affluence in developing nations, is seen as a primary driver of the growing, unsustainable global demand for energy and natural resources.

The future is indeed fraught with environmental, economic, and social risks that could derail progress. For example, the ecological footprint measure assembled by the Global Footprint Network (2011) notes that humanity’s ecological footprint has more than doubled since 1966. The Network’s calculations indicate that if every human today were consuming resources at a level typical of developed countries, we would need three or four planets with natural resources equivalent to Earth.

Recalling the 1975 movie Jaws, some might say, “We are going to need a bigger boat.” But the famous humanist Mark Twain wisely pointed out “buy land, they are not making it anymore.” Constrained by a finite planet, it is clear that today we need a better boat—one that more efficiently uses our fixed resources.

The challenge ahead is to meet the needs of the growing population in a way that restores and maintains the Earth’s natural resources while promoting economic prosperity. This is what “sustainable development” is all about. Sustainability has in turn been widely characterized as resting on three pillars: social well-being, economic prosperity, and environmental protection.

From the perspective of public policy, sustainability is aimed at meeting society’s basic economic and social needs without undermining the natural resource base and environmental quality necessary for continuing to meet those needs in the future. From the standpoint of business and finance, sustainability is evolving into a platform for innovation and value creation at a global market scale for shareholders and society while efficiently using resources and minimizing adverse effects on the environment. The traditional tension between corporate environmental responsibility and profitability is giving way to a convergence between public and private sector interests, as illustrated by numerous examples cited in this article.

Today, government, business, and civil society are developing a shared view of sustainability as a force for spurring innovation, strengthening competitiveness, and enhancing quality of life through transformed leadership of our major institutions. But fundamental changes in institutional approaches are necessary to make this happen. Continuing business as usual is not viable, but change is nontrivial. As one report puts it, “The world is too uncertain and too complex to rely on linear forecasts; therefore, business leaders and policy makers should prepare for the unexpected. This means learning to look at the world in a new way that takes account of globally interconnected megafactors, [and] the causal relationships between megafactors, feedback loops, effective intervention points, and complex scenarios” (KPMG, 2012).

It is essential to anticipate change, understand early warning signals, and take steps to avoid, reduce, and mitigate future problems. A new, more systemic approach to problem solving is needed to avoid unintended consequences, anticipate alternative future scenarios, and strengthen resilience in the face of uncertainty.

One thing is clear to us: the problem that society faces is not the absence of technical or economic solutions, but rather the need to build broad global consensus on a vision and develop the policies and approaches that promote sustainable business and consumer practices. More effective government-government and government-business-society collaboration is needed to address contemporary challenges while avoiding future ones. An essential foundation for such collaboration is adherence to the rule of law, which provides stability and predictability for innovation and investment and a level playing field for business.

This article outlines five steps we feel are needed to accelerate progress toward creating a sustainable future that coming generations deserve:

1. The starting point is that developed and developing countries must better understand the pressures on the global environment and their consequences.

2. This understanding must in turn lead to a vision and strategy to achieve global sustainable development employing specific measures and commitments. Several emerging frameworks—a sustainable or green economy, shared value, and stewardship—present opportunities for accelerated progress in sustainability and must be better understood, integrated, and disseminated globally.

3. It is also essential to promote framework conditions that support good governance at national and local levels.

4. Building on a sustainability framework, advances in science and technology and new business models can enhance resource efficiency across the value chain.
5. Finally, effective collaboration among business, government, NGOs, academia, and civil society can lead to positive actions and outcomes on a global scale.

The Pressures on the Global Environment

Population growth and increased urbanization are two major global megaforces affecting environmental change (KPMG, 2012). They are key drivers of the demand for energy, water, and food, and the resulting degradation and depletion of natural resources. Governments will have to deal with the interactions among these megatrends, and businesses “can expect significant supply chain and price volatility as a result of such rapid growth coupled with increased use of resources” (KPMG, 2012).

A starting point for pressures on the global environment is population growth. From 1950 until 2011, the world’s population nearly tripled, from 2.5 billion to 7 billion people; demographers anticipate that a peak of 9.3 billion people will be reached by 2050. Almost all of the expected population increase will take place in developing nations, where hundreds of millions of people seek greater access to food, water, clothing, shelter, and consumer goods, as well as sanitation, education, healthcare, energy, and communication. Achieving gains in agricultural productivity to feed the growing population will be a major challenge (Foley et al. 2011).

Concurrent with population increase is rapid urbanization that creates pressures on human health, water and energy needs, and waste management. For the first time in history, we are a global urban society where more than half of the world’s population now lives in cities. By 2030, the urban population is expected to reach 5 billion. As the United Nations Population Fund has noted, the “future of cities in developing countries, the future of humanity itself, all depend very much on decisions made now in preparation for this growth” (UNFPA, 2007).

Society’s “to-do” list is economically and socially challenging: we must vastly improve infrastructure for water systems, sanitation, and urban development; lessen hunger, assuage poverty, and promote human dignity; curb greenhouse-gas emissions; avoid persistent, bioaccumulative, and toxic chemicals; and protect biodiversity.

The opportunities and risks of the 21st century, especially in the developing world, are well articulated in the Millennium Project’s 2011 State of the Future Report that gave a mixed review of the world’s present and future:

[T]he world is getting richer, healthier, better educated, living longer, and is more peaceful and better connected; yet half the world is potentially unstable. Food prices are rising, water tables are falling, corruption and organized crime is increasing, environmental viability for life support is diminishing, debt and economic insecurity are increasing, climate change continues, and the gap between the rich and poor is widening dangerously. The world is in a race between implementing ever-increasing ways to improve the human condition and the seemingly ever-increasing complexity and scale of global problems (emphasis in original) (Millennium Project, 2011).

Progress can be made on these issues if developed and developing countries understand the global consequences of humanity’s current oversized ecological footprint, coupled with the pressures of economic growth, increased consumption, and population growth. Hence, step one is to promote a clearer worldwide understanding of these trends and challenges, show how they are connected to one another, and create a sense of urgency for finding solutions. Indeed, the aims of the sustainability conference in Rio in June 2012 are to further global understanding of emerging trends, assess the progress to date on achieving sustainability, and identify new and evolving challenges.

Developing a Vision for the Future: Building a Better Boat for Business and Government

The pressures of population growth, resource use, and economic development are causing both businesses and governments around the world to embrace the concept of sustainable development. Although growth is an inherent characteristic of living systems, some observers even question the viability of continued economic growth (Daly, 2008). Emerging ideas and approaches are focusing on the need to “decouple” economic growth from resource consumption, moving toward a society in which gross domestic product (GDP) is only one measure of progress along with other important indicators of human well-being and greater resource efficiency.

Decoupling is one of the central challenges of our age and potentially “one of the biggest sources of future success for business” (KPMG, 2012). Decoupling economic growth from resource consumption is also the primary theme of the United Nations Environment Program’s (UNEP) International Panel for Sustainable Resource Management that sees it as the largest single challenge facing civilization in our time.
Underscoring our feeling that opportunities abound to meet new challenges, a United Nations (UN) panel argued that prosperity can be achieved with one-fifth of the inputs of energy, water, and mineral deposits typically required for today's technologies (von Weizsäcker et al. 2009). Decoupling to this extent presents a bold and exciting vision for the future. To achieve this target, dramatic technological innovation will be needed in many industrial sectors.

Recognizing that economic indicators such as GDP were never designed to be comprehensive measures of well-being, the European Commission, the European Parliament, the Club of Rome, the Organization for Economic Cooperation and Development (OECD), and the World Wildlife Fund (WWF) joined forces to host a 2007 conference on “Beyond GDP.” The conference aimed at developing indicators as clear and appealing as GDP, but more inclusive of environmental and social aspects of progress (European Commission, 2012a). A report from the Bureau of Economic Analysis in the United States further supported the need for going beyond GDP (Landefeld et al. 2010), a topic that will be debated beyond Rio+20.

In 2011, the European Commission launched the Europe 2020 strategy that aims to shift toward a resource-efficient, low-carbon economy to achieve sustainable growth in the region. This plan provides a long-term framework for actions, supporting policy agendas for climate change, energy, transportation, industry, raw materials, agriculture, fisheries, biodiversity, and regional development. It aims to increase certainty for investment and innovation and to ensure that all relevant policies explicitly consider resource efficiency.

The United States has recently added to this momentum through the first Presidential Policy Directive on Global Development. The country’s global development policy is now intended to focus on sustainable development outcomes that “place a premium on broad-based economic growth, democratic governance, game-changing innovations, and sustainable systems for meeting basic human needs” (Obama, 2010). The Executive Order establishing the President’s Global Development Council adds to this momentum by directing the new entity to provide advice on “innovative, scalable approaches to development with proven demonstrable impact, particularly on sustainable economic growth and good governance” (Obama, 2012).

Building on such developments, society can set together broad goals for the future—such as zero waste, reduced greenhouse-gas emissions, better and broader education, reduced poverty, and enhanced economic prosperity. The UN’s Agenda 21 of 1992 was a first attempt to construct a global vision. Subsequently, many governments around the world drafted their own national action plans: the European Union’s (EU) Europe 2020 plan aims for a “smart, sustainable, and inclusive growth strategy” (European Commission, 2012b).

Reacting to a host of external drivers, many corporations and financial institutions have also begun to develop their own long-term visions and action plans focusing on sustainable practices, efficiency of operation, social development, enhanced competitiveness, and innovation.

- A 2009 Harvard Business Review study declared, “[S]ustainability is a mother lode of organizational and technological innovations that yields both bottom-line and top-line returns” and concluded, “[T]here is no alternative to sustainable development” (Nidumolu et al. 2009).

- KPMG’s 2011 publication “Sustainable Insight” showed that corporations are now valuing sustainability as a driver for long-term business growth, as well as recruitment and retention of talent, in the face of recent global events and megatrends (Schreurs et al. 2011).

- Dozens of Fortune 500 companies have developed sustainability vision statements, goals, and metrics, and have appointed chief sustainability officers or equivalent positions.

- In a survey of nearly 1,000 chief executive officers, 93% asserted that sustainability-related issues will be critical to the success of their business (Lacy et al. 2010).

- An MIT Sloan survey of nearly 3,000 managers in 113 countries reported that 70% of companies that had placed sustainability on their management agendas had done so in the past six years; 20% had done so in just the past two years. Two-thirds of the respondents said that sustainability is necessary to being competitive in today’s marketplace, up from 55% in a 2010 survey (Kiron et al. 2012).

- In 2012, Ceres (a national coalition of investors, environmental organizations, and other public interest groups) organized its “Roadmap to Sustainability” that analyzes the drivers, risks, and opportunities involved in making the shift to sustainability, and details strategies and results from companies that are taking on these challenges (Ceres, 2012).
A KPMG report on megaforces affecting global sustainability defines business strategies to address risks while simultaneously taking advantage of new opportunities (KPMG, 2012).

Sustainable economic growth is thus a business challenge as well as a government mandate. Achieving it will require unified and well-coordinated implementation plans across government, business, and NGOs and the public sector. Emerging concepts such as “the green economy” and “shared values” are important parts of an overall sustainability vision. Rather than viewing the social, environmental, and economic pillars as independent of each other, it is important to understand the interconnections among them and the potential synergies that can result from sustainable practices.

The following sections describe several conceptual frameworks that focus on synergies among the three pillars and have been applied around the world: green economy, shared value, and stewardship.

**Sustainable or Green Economies**

The UNEP defines a sustainable or “green” economy as one in which growth in income and employment is driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services.

Since the EU made sustainability the goal of its Lisbon Strategy in 2000 (European Parliament, 2000), UNEP and OECD have advanced the term “green economy” internationally. The term is not a separate set of production and consumption functions but, rather, the increasing integration of sustainability-oriented innovations, business processes, products, and consumption patterns into day-to-day economic activities. The strength of a green economy is reducing the impact of economic growth on the environment. Consumer awareness and public support of government policies, incentives, and management approaches is essential. The movement toward a sustainable economy reflects the fact that current approaches to resource management (e.g., energy, water, and material use) are not viable, and the unintended consequences of many past choices have resulted in a legacy of challenging environmental problems.

In launching the recent UNEP Green Economy program, Achim Steiner, UN Under-Secretary General and UNEP Executive Director, highlighted what he called two critical shortcomings: failure to think ahead and effectively manage global resources, and weaknesses in global governance (rules and regulations). Steiner said, “The financial, fuel and food crises of 2008 are in part a result of speculation and a failure of governments to intelligently manage and focus markets” (UNEP, 2011).

The thrust of this initiative has been to mobilize and refocus the global economy toward investments in clean technologies and more sustainable infrastructure. A 2011 UNEP policy statement said that the “concept of a green economy does not replace sustainable development, but there is now a growing recognition that achieving sustainability rests almost entirely on getting the economy right” (UNEP, 2011).

As Figure 1 illustrates, the sustainable economy framework focuses mainly on the economic and environmental pillars discussed above. A sustainable economy also provides additional social benefits such as job creation, poverty alleviation, and improved environmental conditions. In particular, the focus on sustainable agriculture and transportation, as well as more ecoefficient manufacturing, will result in improvements in all three pillars.

Implementing the principles of the green economy must be a combined effort among government, industry, academia, and NGOs. Governments must make changes in existing policies and practices that affect regulations, subsidies, incentives, and innovation. For example, in the absence of federal action, many state and local governments in the United States have launched unilateral initiatives to reduce greenhouse-gas emissions and to encourage the development of renewable energy. Likewise, reform in the financial sector will be crucial to the development of innovation that is both sustainable and affordable.

Businesses and industries are central to economic growth, since they are instrumental in the provision of transportation, technologies, infrastructure, housing, manufacturing, and services. Conscious of this, UNIDO launched its Green Industry Initiative in 2009 (UNIDO, 2009) and expanded it in 2011 (UNIDO, 2011). This initiative emphasizes the im-
importance of effective government policies and regulations and business innovation. UNIDO partnership projects around the world have focused on concrete outcomes, ranging from reducing arsenic in Bangladesh to lessening ocean pollution in Egypt, Morocco, and Tunisia. Approaches to sustainable industry focus on upgrading industrial processes and increasing productive capacity without corresponding expansion in resource use and pollution burdens. The goal is to enable industries in developing and transitional economies to participate actively in formulating the solutions needed for continuous improvement in their environmental performance. Thus, green industry is an effective point of entry for, and a driving force in, the transition to a green economy and, ultimately, sustainable development.

Furthermore, from a business perspective, interest in a sustainable economy is being driven by rising energy costs, restrictions on material availability in global supply chains, government regulations, growing consumer awareness, and expanding economic opportunities (Hecht, 2007). A growing number of businesses are therefore more consistently designing products and processes with a greater awareness of environmental constraints and market opportunities (Fiksel, 2009).

Businesses engaged in advancing sustainable practices are evolving their relationships with critical stakeholders and opening the door to a new era of cooperation with government. For governmental bodies, this entails systematic encouragement and creation of an expanded number of sustainable industries constituting a diverse sector of the economy that covers all types of services and technologies.

**Shared Value**

Major companies operating around the world are now moving toward a practice that Michael Porter & Mark Kramer (2011) have called “creating shared value.” Their central premise is that a company’s competitiveness and the health of the communities in which it operates are mutually dependent. Shared value also means shared responsibility. Indeed, human capital—including employee pride and loyalty—is one of the most important intangible success factors identified by investment analysts (Fiksel et al. 2004).

Porter & Kramer identify several ways for companies to realize shared value: fulfilling unmet social needs, increasing supply-chain productivity, and developing “clusters” of highly capable communities to supply goods and services.

As illustrated in Figure 2, the shared value framework focuses mainly on the economic and social pillars discussed earlier. In addition, ancillary environmental benefits result from responsiveness to social needs, such as resource conservation, greener products, and more livable communities.

The chief executive of Nestlé—a company that has proactively embraced the idea of shared value—has declared that “It is not enough for a company just to create value for the shareholder; you also have to create value for the society at large that allows you to act” (Council on Foreign Relations, 2011). In other words, creating shared public trust and confidence enhances a company’s license to operate.

Creating shared value has led Nestlé to focus on “ethical sourcing.” As one of the world’s largest cocoa purchasers, the company responded to protests from activists and consumer groups concerning child labor on cocoa farms in West Africa by developing programs to promote the welfare of millions of small farmers in developing countries.

The business world can thus be a positive force for advancing global environmental security and well-being. In addition to reducing costs and improving the resource productivity of their supply chains, companies can raise the living standards of people around the world and thus contribute to a more sustainable society.

**Stewardship**

Protection of the environment, a traditional responsibility of government, results from concerted public pressure to enact environmental laws and regulations.

In addition, many leading corporations also contribute to environmental, health, and safety protection as part of their commitment to environmental stewardship and social responsibility. Many global industry initiatives, such as Responsible Care® in the chemical industry, include commitment to stewardship over the entire product lifecycle. Responsible Care calls for chemical companies to make health,
safety, and environmental protection integral parts of designing, manufacturing, marketing, distributing, using, recycling, and disposing of products, and drives the companies toward innovations such as providing product-safety assessments in ordinary language.

Stewardship can compensate for market failures by assuring that important public assets are protected and renewed for future generations. In modern practice, stewardship recognizes the interdependence between the health of the individual person, the greater community, and the natural environment. The importance of social capital and the notion of social stewardship have gained traction in the business world.

The latest version of the OECD Guidelines for Multinational Enterprises also puts new emphasis on ethical behavior (OECD, 2011). This update provides voluntary principles and standards for responsible business conduct in areas such as employment and industrial relations, human rights, environment, information disclosure, and consumer interests.

A 2011 study examining the effects of self-reporting on several measures of socially responsible management practices in 58 countries found that such reporting increases the social responsibility of business leaders, raises the priority of sustainable development and employee training, improves corporate governance, reduces bribery and corruption, and increases managerial credibility (Ioannou & Serafeim, 2011).

As sustainability reporting has become a widespread practice, some companies have been accused of “greenwashing”; in other words, paying lip service to environmental stewardship as a tactic to improve their brand value and reputation. However, a lack of genuine commitment can quickly become a liability under the scrutiny of employees, stakeholders, and competitors.

As Figure 3 illustrates, the stewardship framework focuses mainly on the environmental and social pillars of sustainability. Many established corporate responsibility practices contribute to stewardship, including protection of worker safety and ecological resources.

A Systems View of Triple Value Creation

Finally, the three frameworks discussed above can be synthesized to provide a comprehensive, systems view of sustainability. Joseph Fiksel first developed the Triple Value approach described here in connection with the OECD’s program in sustainable materials management (Fiksel, 2006a).

As Figure 4 depicts, the Triple Value model is based on a dynamic stock-and-flow approach that shows the dependency of both industrial supply chains and human communities on ecosystem services. To protect critical natural capital, society must reduce depletion of resources by operating supply chains more efficiently and must reduce generation of unwanted residuals that pollute and degrade the environment.

Figure 4 demonstrates that green economy/industry, shared value, and stewardship provide complementary influences that link the three pillars of sustainability into a resilient overall structure. Governance systems can operate to provide the mechanisms and incentives for decision makers 1) to take into account both positive and negative externalities, 2) to increase efficiency by reducing transaction costs, and 3) to combat corruption that can distort decision making.

It is important to note that the frequently used phrase “triple bottom line” does not identify the important value drivers for sustainability. The financial “bottom line” is a short-term measure of cash flow that does not reflect the importance of capital preservation and renewal for sustainable value creation. Moreover, accounting separately for economic, social, and environmental performance fails to recognize the inherent synergies among these three dimensions. Corporations have only one bottom line, but the benefits derived from economic, social, and environmental synergies are blended into triple value creation for companies, society, and nature.

To help implement the above synthesis, it remains essential that proper governance systems be in place: the rule of law and effective public policies are essential to ensure stability and promote investment (UNIDO, 2011). Effective national and local governance is also necessary to provide a level playing field for businesses operating globally and to help avoid the emergence of pollution havens. Multilateral
agreements are typically implemented through corresponding national laws and institutions, making good national governance essential for the parties to realize the benefits contemplated by international agreements. Thus, it has become evident that “without good governance, neither global nor domestic aspirations can be realized” (Fulton & Benjamin, 2011).

**Tools and Approaches for Building a Better Boat**

Practical realization of the sustainability vision requires scientific tools and approaches, social change, good governance, and a new era of government-business collaboration. While sustainability is a commonly stated goal, how to make it operational is the key test. The following discussion describes important tools and approaches for realizing sustainability on a national and global scale—effective governance, scientific innovation, and collaboration.

**Effective Governance**

Implementation of green economy and stewardship policies depends on effective national and sub-national environmental governance. The United Nations Global Compact (2012) has recommended that governments take action to build “effective policy frameworks to support corporate sustainability, specifically related to: peace, stability, and human rights; an open, rule-based, and non-discriminatory policy environment; good governance and corruption; and effective regulatory frameworks and incentives for markets.”

Over the past few decades, experience around the world has pointed to a number of general precepts for good environmental governance. These key building blocks for sustainable development and effective national (and subnational) governance appear relevant despite differences in the nature of environmental problems, cultural context, and governmental structure:

1. **Environmental laws should be clear, even-handed, implementable, and enforceable.** Laws and regulations should be designed to facilitate conversion of general mandates into facility-specific requirements that lend themselves to implementation and enforcement.

2. **To optimize the uptake and resilience of such requirements, stakeholder views should be considered in their formulation.**
3. **Environmental information should be collected, assessed, and disclosed to the public.** Routine disclosure of environmental information allows civil society to help promote accountability and encourages businesses to self-regulate more effectively.

4. **Affected stakeholders—civil society and regulated entities alike—should be afforded opportunities to participate in environmental decision making.** This should include the opportunity to participate at a predecisional stage and to challenge government decisions that are not grounded in science and law.

5. **Environmental decision makers, both public and private, should be accountable for their decisions, including through effective enforcement and compliance-assurance programs.** Accountability ensures public confidence in the impartiality and public purpose of government actions, serves to create a procompliance business environment, and helps ensure that the cost of environmental degradation is born by polluting enterprises rather than by the public at large.

6. **Roles and lines of authority for environmental protection should be clear, coordinated, and designed to produce efficient and nonduplicative administration of environmental protection.** Well-defined roles and coordination mechanisms among government agencies—as well as a clear division of labor between national, provincial, and local levels of government—can foster efficiency, enhance effectiveness, provide regulatory clarity for the business community, and prevent implementation conflicts.

7. **Affected stakeholders should have access to fair and responsive dispute-resolution procedures.** To play effectively its vital role as guarantor of the protective benefits of environmental law, the judiciary must provide impartial, timely, and responsive dispute resolution. Outcomes must be consistent, predictable, and geared to eliminating the potential economic advantages of unsustainable and polluting behaviors.

8. **Public integrity in environmental program delivery is essential to achieving environmental protection and sustainable development.** Corrupt or unprincipled environmental decision making frustrates program implementation, distorts environmental results, and erodes public confidence in the environmental rule of law. Anticorruption efforts, ethical requirements, and independent oversight are thus critical.

Recognition of these eight core precepts of effective governance systems based on the rule of law—and attention to improving national and local governance in each of these areas, treating them as interrelated and mutually supporting—is essential to providing a stable foundation for innovation and investment and for building collaborative partnerships.

**Science, Technology, and Innovation**

Today more than ever, the constructive power of science, technology, and innovation can propel mankind to new levels of global well-being. Innovation is crucial to meet any number of visions aimed at reducing the global footprint and decoupling economic growth from environmental impacts. Science can help to anticipate problems, devise effective solutions, and support decision making. The growth of Internet use and social marketing is a clear example of the power of science and technology. The positive impacts of advances in science and technology are clear to both business and government.

Many companies have leveraged information and communication technology to track and manage material flows across global supply chains and to develop more sustainable management practices. Innovative materials and production processes, as well as “smart systems,” can offer dramatic reductions in energy and natural resource consumption, increase resource productivity, and serve as a competitive differentiator.

Some innovative trends may add environmental stressors that need to be offset. For example, while new products such as electronic devices are becoming smaller and more energy efficient, market growth, supply-chain complexity, and rapid obsolescence can actually increase the lifecycle environmental burdens of these products. In some cases, new electronic products use more power than the ones they are replacing (Horowitz et al. 2005).

The scientific basis for sustainability is strong but requires additional development. Traditional environmental science approaches (as recognized by a National Science Foundation report) must “move beyond identifying issues and toward providing sound bases for the development of innovative solutions, effective adaptation, and mitigation strategies” (National Science Foundation, 2009). The same document notes, “[w]e urgently need to expand our capacity to study the environment as an integrated system that includes the human dimension” (Stafford et al. 2010).

One step in that direction is the emergence of “sustainability science” which aims to link many
scientific disciplines to create an integrated systems approach to problem solving. Sustainability science has been described as “accelerating favorable trends, slowing harmful trends, understanding complex trends, and noting changes in direction and inflection that constitute significant departures” (Kates & Parris, 2005).

Sustainability science builds on several crucial ideas:

1. **Applying integrated systems thinking:** This approach is especially important in assuring that pollutant emissions or impacts are not merely shifted from one medium to another. An air problem today should not become a water problem tomorrow.

2. **Anticipating and responding to growing stressors:** Over the second half of the twentieth century, while world population more than doubled, food production almost tripled, energy use more than quadrupled, and the overall level of economic activity quintupled. This creates new challenges for protecting human health and the environment from pollution and overconsumption of natural resources.

3. **Adopting a transdisciplinary approach to problem solving:** Sustainability science is defined by the problems it addresses rather than by the disciplines it employs. It applies research and analysis that draws on relevant science and social science disciplines. It aims to solve problems by having all stakeholders be part of the research planning, design, and implementation of results.

4. **Promoting innovation:** Many established approaches and practices are unlikely to provide pathways to the future. Stimulating and adopting new and innovative solutions, including new technologies, are necessary approaches to solving sustainability problems.

5. **Seeking realistic solutions:** Going beyond just defining a problem, sustainability science brings together all appropriate tools and approaches to help find practical solutions to real-world problems. Helping policy and decision makers make better and more informed decisions is a key goal of sustainability science.

6. **Advancing resilience:** Understanding the vulnerability and resilience of environmental, economic, and social systems is critical for establishing a sustainable society. The most common definition of resilience is drawn from the engineering sciences: the capacity to absorb disturbances and to return to a prior (relatively stable) state. However, resilience in a turbulent environment requires the capacity to adapt and transform existing systems (Fiksel, 2006b).

Strengthening the link between science and health is crucial. More than 100 million people in the United States are estimated at risk from toxic pollution that exceeds international health standards (McCartor & Becker, 2010). China is an unfortunate example demonstrating that pollution problems often accompany rapid economic growth: it has 16 of the world’s 20 most polluted cities (Worldwatch Institute, 2007).

In its *World’s Worst Pollution Problems Report 2010*, the Blacksmith Institute identifies lead, mercury, chromium, arsenic, pesticides, and radioisotopes as pollutants that seriously threaten the health of millions of people (McCartor & Becker, 2010). As a public health issue, pollution is as salient as tuberculosis, malaria, and HIV/AIDS, and should receive increased attention and resources. This is a critical area where government and business must work together.

Green chemistry is one innovative approach that can help industry and government promote sustainable manufacturing and protect human health. The concept of green science and technology is still at its earliest stages in most African countries, but the Pan Africa Chemistry Network has held the first annual Africa Green Chemistry Congress in Addis Ababa (PACN, 2010). Similar initiatives are emerging in India, China, and other nations, signaling the potential for adoption of green chemistry practices around the world.

There is growing recognition in the business community that the pursuit of sustainability holds great potential for innovation and public-private collaboration. Here are some recent examples:

- Collaboration between Dow Chemical and The Nature Conservancy to advance the science and practice of valuing ecosystem services (Walsh, 2011).

- An IBM and the World Environment Center “Innovations for Environmental Sustainability Council” involving some of the world’s leading companies established to identify next generation technologies and best practices to address critical sustainability challenges (Fellow, 2012).

- Emergence of industry consortia—such as the Sustainable Apparel Coalition, Outdoor Industry Association, and the Sustainability Consor-
A collaborative initiative between UNEP, Dow, and China’s Ministry of Environmental Protection to promote safer production, chemical safety, and emergency preparedness in China’s chemical industry value chain.

- Blossoming of collaborations between businesses and environmental groups such as the Environmental Defense Fund.

These initiatives stem from a growing awareness that sustainability creates shareholder value in several ways: tangible financial returns, enhancement of intangible assets such as reputation and human capital, and delivering value to stakeholders that indirectly strengthens intangible assets (Fiksel et al. 2004).

Global Collaboration

We live in a world of extreme contrasts where some enjoy great wealth and millions live on less than a dollar a day. Substantial economic growth in the first half of the decade reduced the number of people in developing regions living on less than US$1.25 a day from 1.8 billion in 1990 to 1.4 billion in 2005, while the poverty rate for this period dropped from 46% to 27%. The UN Millennium Development Goals aims to reduce the overall poverty rate to 15% by 2015. However, this reduction has been concentrated in one nation—China (OECD, 2010). While many other countries have made progress in expanding their economies, the benefits of development have not been distributed equally, and poverty reduction still represents a major challenge for both the industrialized and developing worlds.

It is now clear that an improved understanding and vision of sustainability is needed around the world. This is the motivation behind a UNIDO initiative to support national learning and innovation hubs “that bring together the business community, academic development and realization of sustainable pathways” (UNIDO, 2011). This can be done through applied research, technology development, teaching, and training.

While many governments claim to recognize the linkage of the social, economic, and environmental pillars, their relative importance can differ vastly from one region of the world to another. For example, health issues are predominant in many developing regions, since only 62% of the global population has access to improved sanitation and 884 million people—more than one in eight—lack access to safe water supplies, contributing to the deaths of more than 3.5 million people each year from water-related diseases (UNICEF/WHO, 2008). In the developing world, 24,000 children under the age of five die every day from preventable causes, such as diarrhea contracted from unclean water.

As the above example makes clear, these complex issues are not divorced from environmental impacts and business operations, so connecting the dots is critical. The issues are more than governments alone can effectively address. The challenge ahead is whether government, industry, academia, and NGOs can collaborate effectively both to deal with these daunting problems and to anticipate, plan for, and avoid future problems.

In this context, we need a new era of international business-government collaboration and a shared vision embodied in the concept of sustainability. Business enterprises offer a powerful engine for structural change, job creation, income generation, and social well-being, but they are constrained by existing markets, regulatory frameworks, and established technologies.

Governments also need to collaborate with other governments. For example, American and European intelligence agencies have pioneered a number of studies aimed at identifying future problems and planning appropriate responses. The 2010 “Global Governance Report for 2025,” prepared by the U.S. National Intelligence Council (NIC) and the EU’s Institute for Security Studies, points out the “interconnected nature of the challenges on the international front” (EUISS, 2010).

While there is not necessarily agreement on all major issues, this report provides consensus on the need for stronger international management of energy, food, and water resources. The document sees the potential for serious international conflict: “Resource competition in which major powers seek to secure reliable supplies could lead to breakdown in cooperation in other areas. Moreover scarcities are likely to hit poor states the hardest, leading in the worst case to internal or interstate conflict and spill-over to regional destabilization” (EUISS, 2010).

The joint report recognizes that “non state actors” need to work together to change global thinking:

On a positive note, transnational nongovernmental organizations, civil-society groups, churches and faith-based organizations, multinational corporations, other business bodies, and interest groups have been equally, if not more, effective than states at reframing issues and mobilizing public
opinion—a trend we expect to continue (EUISS, 2010).

Collaboration with stakeholders is also crucial. In an MIT Sloan survey, company leaders were asked what lessons they have learned from successful implementation of sustainability practices. Implementation of new practices by “harvester” companies sometimes demands new approaches. The survey showed that “harvesters not only change themselves in response to sustainability considerations, but they also become more collaborative with stakeholders inside and outside of the company” (Haanaes et al. 2012).

Achieving the Future We Want

In a recent report on sustainability and the Environmental Protection Agency, the National Research Council defined sustainability as both a goal and a process (NRC, 2011). Such a definition is especially relevant on the global stage. Governments, companies, academia, and civil society around the world are far from being aligned with respect to future actions. To realize sustainability, global collaboration is needed, not only to develop alignment on shared goals but also to assure that the processes being adopted are responsive to those goals and sufficiently resilient to adapt to changing conditions and priorities.

The world of the twenty-first century must go beyond mere compliance with existing laws and instead recognize the connections among the three pillars and anticipate and plan actions to prevent future problems. It is important to continue to establish adequate roadmaps and to identify relevant targets and indicators that facilitate benchmarking the green economy/industry performance. These indicators will show how businesses, sectors, and countries are performing in terms of resource use and productivity and generation of wastes and emissions, as well as social and economic contributions relevant to sustainable development.

What we have seen from this article is that opportunities abound but challenges remain. Our conclusions are five-fold:

1. The world is not on a sustainable path. Our current oversized footprint, augmented by continuing economic and population growth, will result in increasing pressures on energy, water, land, and food, which in turn stress both government and business.

2. Global megatrends are driving science, innovation, and new business models that can help solve present and future problems, but existing innovative approaches and business models must be scaled up.

3. Several emerging frameworks—good governance based on the rule of law, green economy, shared value, and stewardship—present opportunities for accelerated progress in sustainability. These frameworks must be better understood, integrated, and disseminated globally.

4. The positive linkages among economic growth, social well-being, and environmental protection are not fully appreciated or understood. Further research and education are clearly needed.

5. New collaborations are needed between business, government, academia, and NGOs.

We began and end this article on an optimistic note. We are fortunate that many governments and businesses view sustainability as a means to enhance competitiveness and human well-being by reducing costs and long-term risks. We believe that in the world ahead seizing opportunities for innovation and partnership can help to overcome both current and emergent challenges. Advances in science and technology and in business practices are promoting sustainable solutions, although more needs to be done. Hence, we firmly believe that global sustainability can be realized through effective collaborations, green business strategies, enlightened regulations and policies, and public support and understanding.

Authors’ Note
The perspectives expressed in this article are those of the authors and do not necessarily reflect the views or policies of their affiliated organizations. Mention of trade names or commercial products does not constitute agency endorsement or recommendations for use.

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“Creating the Future We Want” by Alan Hecht et al. presents a policy approach designed to address a range of social, economic, and environmental issues, grouped under the heading of sustainability. The approach is a version of “doing good by doing well” (Bonini & Mendonca, 2011). It emphasizes alignment of interests and actions between government and business. The opening paragraph conveys the article’s tone:

Over the next two decades, governments and businesses will face serious environmental and social changes that hold both risks and opportunities. We are optimistic that we have the capacity to meet these challenges and achieve a strong global economy while advancing social well-being and protecting human health and the environment.

Based on a wide-ranging discussion, Creating the Future reaches five conclusions. The article then ends with the following remarkable statement:

Hence, we firmly believe that global sustainability can be realized through effective collaborations, green business strategies, enlightened regulations and policies, and public support and understanding.

Note the choice of words. The authors of Creating the Future are not just hopeful or even reasonably certain. They “firmly believe” that one of the most difficult problems to ever face humanity—achieving global sustainability—will yield to a policy approach of their devising. Reading the article raises concerns about the degree of optimism expressed and the treatment of alternative approaches. The five conclusions provide a convenient framework for a discussion of these issues.

1. The world is not on a sustainable path. Our current oversized footprint, augmented by continuing economic and population growth, will result in increasing pressures on energy, water, land, and food, which in turn stress both government and business.

The global footprint is used as an indicator of the current situation. The recently developed planetary boundaries (Rockström et al. 2009) better convey the uncertainty concerning the “safe operating limits for humanity” that exists at the level of basic science. For two of the nine boundaries—chemical pollution and atmospheric aerosol loading—a preliminary estimate of the safe operating level has yet to be established. The other seven are characterized by their developers as “rough, first estimates only, surrounded by large uncertainties and knowledge gaps.” Without any mention of the difficulties involved in setting a scientifically based boundary for chemical pollution the article cites a number of efforts including Responsible Care, an initiative by the chemical industry to address issues of health, safety, and environmental protection. Creating the Future would increase its credibility if the degree of basic scientific uncertainty that accompanies such efforts were at least clearly stated.

2. Global megatrends are driving science, innovation, and new business models that can help solve present and future problems, but existing innovative approaches and business models must be scaled up.

Successful scaling up is central to the approach put forward in Creating the Future. There are substantial challenges to such scaling. The effort to commercialize some apparently promising innovations can take decades. For example, commercialization of fuel cells had been underway for over 25 years back in 1995 (Appleby, 1995). It is still underway today. Other innovations, such as more efficient light bulbs, have achieved only a small fraction of their physical and economic potential (Mills, 2002). After decades of experience, mounting programs to foster the adoption of cost-effective innovations remains a challenge (Cowart & Hamilton, 2009). Given the importance of scaling up for the approach pro-
posed in Creating the Future, some discussion of its challenges and limitations would be appropriate.

3. Several emerging frameworks—good governance based on the rule of law, green economy, shared value, and stewardship—present opportunities for accelerated progress in sustainability. These frameworks must be better understood, integrated, and disseminated globally.

The emerging frameworks cited address primarily the supply side of the economy. Creating the Future gives very limited consideration to the role of consumers, individually or as a group. Beyond developing “awareness” consumers play no role in the development of a green economy. Consumers do play a role in stewardship, but only by providing “concerted public pressure.” Throughout the discussion, they are always supporting actors. This is made very clear in the heading chosen for the third section, “Developing a Vision for the Future: Building a Better Boat for Business and Government.” In fact, thoroughly addressing consumers—and the demand side of the production-consumption system more generally—is essential to the understanding, integration, and dissemination of the article’s three frameworks. This is made clear in work leading to a Nobel Prize in Economics (Kahneman, 2011), well-known efforts to apply behavioral economics to foster sustainability (Thaler & Sunstein, 2008), and a burgeoning journal literature addressing sustainable consumption (see, e.g., Thøgersen & Schrader, 2012). Discussions in the journal literature recognize that consumers need to be considered alongside business, government, and nongovernmental organizations (NGOs). To achieve its goals, Creating the Future will need to do the same.

4. The positive linkages among economic growth, social well-being, and environmental protection are not yet fully appreciated or understood. Further research and education are clearly needed.

One hopes that the authors of Creating the Future are interested in understanding all of the important linkages among the factors mentioned so that they can devise policies designed to strengthen those that are positive and mitigate those that are not. There is a large body of literature that addresses negative linkages between economic growth and the other two factors. The negative linkage with the environment has been discussed for some time (see, e.g., Mishan, 1993). It provides the impetus for the development of the approach described in Creating the Future. The negative linkage between economic growth and social well-being has also been a concern for decades (see Leipert, 1986). Recently, the connection between economic growth and increased inequality leading to adverse social impacts has attracted particular attention (Wilkinson & Pickett, 2009). There are serious questions about the malleability of these negative relationships. The authors of Creating the Future should reframe their fourth conclusion, making the need to understand the full range of linkages clear. They might also consider acknowledging that, even with much effort, substantial negative connections may remain.

5. New collaborations are needed among business, government, academia, and NGOs.

Collaborations might, in principle, involve representatives from any or all of the four groups listed. However, as Creating the Future makes clear through its choice of examples, what is really meant here is collaboration between businesses (or their trade associations) and some or all of the others. The article provides six bulleted examples. In all of them, business plays a major role. In all of them, attention is on product development or production, the issues of immediate concern to business. This narrow focus is not supported by historical experience. Consider the issue of health in developing nations that Creating the Future highlights. A collection of twelve national-level case studies of past “success stories” shows the importance of collaboration between government agencies and by them with NGOs, but not with business (Riley, 2003). In sum, the article’s fifth conclusion is correct, but the discussion that accompanies it is inappropriately narrow.

* * *

When reading Creating the Future, it is important to be aware that there is a fundamental divide between those actively in pursuit of a sustainable future. One group, including the authors of Creating the Future, stresses economic growth as part of a transition to sustainability. The other group argues that limitations on such growth, particularly for the current high-income nations, will be an essential part of a transition (Jackson, 2009). These two approaches each raise thorny issues. A central problem for the position taken in Creating the Future is the difficulty in achieving decoupling, that is having the economy grow while the associated impacts on the environment decline. Recent reports have discussed the feasibility in principle (von Weizsacker et al. 2009) and the remaining physical, economic, and political challenges (UNEP, 2011). Decoupling is difficult, in part because the feedback between improvements in resource efficiency and growth in the economy is still
poorly understood (Herring & Sorrell, 2009). The alternative position raises concerns about the feasibility and desirability of limiting economic growth in high-income nations. These issues have been addressed in some detail (see, e.g., Victor, 2008), but are not fully resolved.

The magnitude of the threat that changes in the environment pose for humanity is well known to the scientific community. The opening lines in a recent book by James Hansen (2009) convey the sense of urgency quite clearly: “Planet Earth, creation, the world in which civilization developed, the world with climate patterns that we know and stable shorelines, is in imminent peril.” If progress is to be made, it is essential that conversation among those seeking a sustainable future continue. If materials that reflect one position are to receive serious consideration by the supporters of the other, the materials must, at a minimum, demonstrate a recognition that the other position exists and that it brings important points to the table. Unfortunately, Creating the Future does not meet this requirement. A balanced treatment of other perspectives would make the article more credible as an exposition of its position and more useful as a basis for discussion.

References


POLICY DEBATE

Rejoinder: Creating the future we want

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We thank John Stutz for his review and comments on our article. He raises a number of salient points to which we would like to respond.

1. Scientific uncertainties about the impacts of industrial emissions. We agree that the analysis of “safe operating limits for humanity” by Rockström et al. (2009) is a useful summary of global stressors and that the uncertainties surrounding chemical pollution are daunting. Both regulators and the chemical industry are grappling with the challenge of characterizing the health and environmental effects of thousands of chemicals, with new molecules constantly being developed. As we mentioned, one promising development is the adoption of green chemistry principles to formulate more benign substances, for which the Environmental Protection Agency (EPA) and others are pursuing important developments in computational toxicology (CompTox). Traditional testing for chemical toxicity is expensive and time consuming and requires extensive animal experimentation. CompTox conducts innovative research that integrates advances in molecular biology, chemistry, and computer science to more effectively and efficiently rank chemicals based on risk. The outcome from this research is rapid chemical-screening data (ToxCast™) and decision-support tools to limit potential risks to humans and the environment.

2. Scaling up of new technologies and practices. Dr. Stutz correctly points out the potential difficulty in scaling up sustainable innovations, a process that has historically often been slow and disappointing. However, history need not repeat itself. We argue that global collaboration is necessary to create the market signals and framework conditions that will encourage rapid adoption of new technologies and practices. For example, reducing subsidies for traditional fuels and introducing financial incentives for capital investment and technology conversion would accelerate a shift toward renewable, low-carbon energy sources.

3. Importance of encouraging sustainable consumption. Dr. Stutz makes the important point that consumer behavior will be an essential driver of a green economy. Indeed, we believe that public understanding and support are needed to enable the profound changes that we envision, and that consumer awareness is essential for “greener” purchase decisions, especially when extra costs are incurred. We put a stronger emphasis on business and government collaboration to activate sustainable consumption on a large scale. Areas for collaboration include lifecycle-assessment tools to understand the full impacts of alternative designs and communication tools to inform consumer behavior. Such collaborative initiatives are already under way, including the Sustainability Consortium initiated by Walmart, the Keystone Center’s Green Products Roundtable, and the activities of the General Services Administration (GSA).1

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4. **Negative linkages between economic growth and sustainability.** As indicated in the beginning of our article, we are acutely aware that economic growth can contribute to environmental degradation if not addressed in a sustainable manner. Our main goal is to outline a strategy for breaking this pattern. As we stated, one of the grand challenges of our time is decoupling economic growth from negative environmental and social impacts. This is why we endorse the idea of going beyond the use of gross domestic product (GDP) as a measure of progress. However, as Dr. Stutz suggests, one should not ignore the potential for continued negative consequences; for example, in many nations economic growth has exacerbated income gaps. We argue for a comprehensive systems approach that fully accounts for both positive and negative feedback loops and avoids oversimplified policy initiatives.

5. **Role of the business community.** While Dr. Stutz recognizes the importance of collaboration between business and government, his analysis highlights the roles of nongovernmental organizations (NGOs), civil society, and consumers. While our article emphasizes business-government collaboration, we fully accept the roles of all stakeholder groups, which are especially vital in areas such as human health and social and environmental justice.

6. **Economic growth vs. limited growth.** Dr. Stutz suggests a “fundamental divide” between those who stress economic growth as a part of the transition to sustainability and those who focus on limiting growth. We maintain that economic growth with a reduced footprint on the environment is essential. Economic development will continue to be a central goal for human communities around the world. Decoupling is admittedly difficult, because of the “re-bound effect,” i.e., the stimulation by increased efficiency of increased resource consumption. There will certainly be factors that limit economic growth, primarily resource scarcity. The overarching challenge is to achieve a resilient and sustainable pattern of growth that avoids painful economic shocks and disruptive conflicts over resources. That is the future that we want.

Our motivation for writing this paper was the convergence of government, business, and NGOs in Rio de Janeiro in June 2012. We surveyed the sustainability landscape from our diverse perspectives. In many arenas, we see disturbing trends that could impede economic prosperity, social well-being, and environmental protection. All of us feel strongly that global leadership, collaboration, and education are needed to address these threats and firmly believe that humanity has the capacity to overcome them by taking swift and decisive actions. Our optimism is tempered with realism, but we are encouraged by the apparent emergence of a global consensus on the urgency of the situation.

**Authors’ Note**
The perspectives expressed in this article are those of the authors and do not necessarily reflect the views or policies of their affiliated organizations. Mention of trade names or commercial products does not constitute agency endorsement or recommendations for use.

**References**
COMMUNITY ESSAY

Climate-change mitigation and adaptation in small island developing states: the case of rainwater harvesting in Jamaica

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Author’s Personal Statement:

This essay seeks to further the dialogue concerning climate-change impacts for small island developing states (SIDS). Climate-change adaptation and mitigation strategies must be developed to cope with changes such as shifting precipitation patterns, increasing evapotranspiration, and expanding saline intrusion into coastal aquifers and wells. While it is necessary to study all climate-change mitigation measures, this essay uses Jamaica as a case study to examine the utility of rainwater harvesting (RWH) in SIDS. What role can RWH play in providing a sustainable supply of water in a changing climate? Through various water demand and deficit scenarios, questions are answered regarding (1) how much rainwater can be harvested on the island given present and future precipitation patterns and (2) how much can RWH realistically curb water-supply deficits now and in the future. Water resources are directly linked to many other considerations, including infrastructure, energy, agriculture, and the overall economy. Exploring the aforementioned questions can help to facilitate more effective policy decisions for water resources given predictions for rainfall. It is my hope that this analysis spurs a broader reflection on what concrete actions SIDS should take to prepare for the water-resource impacts of climate change.

Introduction

Climate change presents great challenges for small island developing states (SIDS).¹ SIDS are generally low-lying and coastal nations that range in size from Papua New Guinea (more than 450,000 square kilometers or km²) to Tokelau (10 km²) (Schmidt, 2005). These nations are found throughout the world, although most of them are located in the wider Caribbean and South Pacific regions. Ninety percent of SIDS are in the tropics and many are members of the Alliance of Small Island States.² The Intergovernmental Panel on Climate Change (IPCC) has labeled SIDS as the nations most vulnerable to climate change (see Payet & Agricole, 2006). The United Nations Framework Convention on Climate Change lists the following characteristics of SIDS that render them particularly at risk (UNFCCC, 2005):

- Limited natural resources, with many heavily stressed from human activities
- Coastal concentration of population, socioeconomic activities, and infrastructure
- High susceptibility to frequent and increasingly intense tropical cyclones and associated sand and storm surges, and to droughts, tsunamis, and volcanic eruptions
- Dependence on freshwater resources that are highly sensitive to sea-level changes
- Relative isolation and significant distance to major markets
- High sensitivity to external shocks
- High population densities (and in some cases high population growth rates)
- Inadequate infrastructure
- Limited physical size, which eliminates some adaptation options to climate change
- Insufficient financial, technical, and institutional capacities.

These factors challenge the developmental prospects of SIDS by serving as a barrier to accessing foreign markets and developing domestic products and services. The susceptibility to cyclones and droughts prevents some industries such as agriculture and water-dependent manufacturing from operating at optimum levels. Limited size creates intense competition for land use (residential, agricultural, industrial, institutional, and conservational uses), which

¹ For a list of SIDS, see http://www.un.org/esa/sustdev/sids/sidslist.htm from the United Nations Department of Economic and Social Affairs.
² Established in 1990, AOSIS is a coalition of small island and low-lying coastal countries that share similar development challenges and concerns about the environment. Member states of AOSIS work together primarily through their diplomatic missions to the United Nations.
makes land-intensive adaptive measures to climate change difficult.

This essay focuses on Jamaica to highlight the problems encountered by SIDS and devotes particular attention to an analysis of climate change and water resources in this Caribbean nation. Included is an overview of climate and precipitation in Jamaica, threats to water resources due to climate change, and rainwater harvesting as a possible response. The objective is to answer key questions regarding the potential of rainwater harvesting as a strategy to mitigate water shortages due to climate change.

The Climate-Water Nexus in Small Island Developing States

The climate-change impacts on water resources are especially troublesome for SIDS. These consequences include decreases in already limited freshwater availability (due to changes in rainfall patterns, saline intrusion of freshwater aquifers from sea-level rise, changes in El Niño intensity and frequency), increased incidence and intensity of floods and changes in storm tracks, impeded drainage and elevated water tables, and heightened frequency and severity of droughts (UNFCCC, 2005).

Extreme weather events pose health risks as well as cause physical and infrastructure damage. In the Caribbean, risks include insect-borne, rodent-borne, water-borne, food-borne, and respiratory diseases, and heat-related illnesses (Ebi et al. 2006). In May and September, 2002, Jamaica experienced major flooding that resulted in four deaths, relocation of 725 people, and infrastructure damages worth US$1 million (WHO, 2003).

The tourism industry, water resources, and climate change in SIDS are highly interlinked. Tourism is a major economic contributor in many small island countries. However, the coastlines that attract visitors are also at risk of damage due to climate change. Thus, in addition to the environmental and social consequences of climate change, SIDS may face disproportionate harm to the economy due to loss of tourism. For instance, tourism has been the most important economic sector in Barbados for the last twenty years and provides critical foreign exchange earnings (Emmanuel & Spence, 2009). Tourism also requires a high quantity of water to service hotels and related facilities and the high season often coincides with the dry periods of the year in many SIDS. The average consumption for hotels in Barbados, for example, is 678 liters per guest per day; tourists consume roughly 3.6 times more water per capita per day than residents (Emmanuel & Spence, 2009). Finding strategies to cope with the impacts of climate change on water resources is therefore particularly important for the small island tourism sector.

There are many reasons for mitigation and adaptation planning for climate change. One reason is the irreversible nature of some changes in climate (which we are already undergoing). Another reason is the uncertainty of future actions to curb climate change due to conflicting national interests and to time needed to develop new technologies and deploy existing technologies and strategies that will reduce greenhouse gas (GHG) emissions. Existing strategies include behavioral changes, such as changing our means of transportation (e.g., to mass transit, electrical vehicles), using energy-efficient devices (such as light bulbs and appliances), and consuming products with less embodied energy. However, there are also various barriers to effective climate change adaptation planning. In SIDS, these obstacles consist of long time scales (climate-change effects are gradual and a discount rate may be needed to appreciate the net present benefits of action plans) (Tisdell, 2008), disagreement about climate-change priorities (e.g., water availability, coastal protection, energy sources), scientific uncertainty about the time-path of climate-change impacts, and financial constraints to many stagnant economies.

In addition, some adaptation strategies pose serious socioeconomic challenges, especially those in response to sea-level rise (such as coastal retreat). This article focuses on one mitigation and adaptation strategy for Jamaica: rainwater harvesting (RWH). RWH, though an ancient and proven technology, is underdeveloped in national policy. However, it is an intervention worth analyzing and deploying for various reasons: RWH is easily deployable given the fact that materials are found locally and there is a basic familiarity with the technology, empowers households and communities through decentralized implementation, can be encouraged through mandates and tax benefits, and brings people closer to the water source thereby limiting wastage and encouraging water savings.

Water-Resources Adaptation in Jamaica

Even Jamaica, an island with abundant rainfall, can experience water shortages in the dry season, which begins in December and ends in April. These dreaded droughts, exacerbated by climate change, can bring water restrictions and economic hardship upon various industries and communities (such as tourism and agriculture-based areas). Jamaica’s poorest households (measured by household per capita income) spend on average over 10% of their income on water, while in the United Kingdom, for example, spending 3% of family income on water is considered
the hardship threshold (UNDP, 2006). This statistic helps to demonstrate the important link between access to water and economic development. While Jamaica seeks to increase the proportion of its population with access to safe water, climate change challenges this goal. Implementing mitigation and adaptation solutions for water supply is thus imperative.

Climate and Precipitation in Jamaica

Jamaica has a tropical climate with average temperature ranges from 26°C in February to 30°C in August (WRA, 2011). The island experiences tropical storms and hurricanes frequently during the July to November season. Precipitation can vary both seasonally and spatially. The average annual precipitation from 1881 to 2007 was 1,871 millimeters (mm) (ESL Management Solutions Limited, 2009). The Blue Mountain area receives over 5,080 mm of annual rain, while the capital city of Kingston receives less than 762 mm (WRA, 2011). The dry season runs from December through April and coincides with the season of cold fronts (ESL Management Solutions Limited, 2009).

There are three rainfall-area characterizations in Jamaica: (1) heavy rainfall area (northeast section, Cockpit country (contiguous rainforest in Trelawny), parts of the parishes of Hanover and Westmoreland), (2) moderate rainfall area (north coast from Port Maria to Negril Point and the central regions of the island), and (3) low rainfall area (south coast between Bull Bay—on the southeast coast in St. Andrew—and Black River, as well as the north coast between Discovery Bay and Montego Bay) (Scientific Research Council of Jamaica, 1963). Figure 1 shows a map of Jamaica’s parishes and rivers.

Climate Change and Jamaica’s Water Resources

Climate change is expected to affect various aspects of the environment, especially water resources. Temperatures in Jamaica are expected to rise by about 1.5°C by the 2050s and by 2.8°C by the 2080s (ESL Management Solutions Limited, 2009). Some impacts of climate change on the water sector in Jamaica comprise shifts in precipitation patterns, a reduction in water availability in basins fed by shrinking glaciers (due to rising atmospheric temperature), an increase in algal blooms and reduction of self-purification capacity in water bodies (due to higher surface-water temperature), saline intrusion into coastal aquifers and wells (due to sea-level rise), and an increase in evapotranspiration (water availability reduction, lower groundwater levels) (Bates et al. 2008). Up to 80% of Jamaica’s freshwater is supplied by groundwater, which can become salinated with sea-level rise (MACC, 2010). Changes in precipitation patterns will mean an extension in the length of the dry season (ESL Management Solutions Limited, 2009), an increase in frequency and intensity of floods and droughts (Bates et al. 2008), and a rise in stress during droughts for nonirrigated agriculture (irrigated agriculture accounts for only 9.3% of cultivated lands in Jamaica) (ESL Management Solutions Limited, 2009).
The National Water Commission provides most of the public water supply in Jamaica. In 2005, annual water production was nearly 300,000 megaliters (ML) and annual water consumption was 94,415 ML (ESL Management Solutions Limited, 2009). However, even without climate-change factors, there are three water-stressed catchments in Jamaica. The water stress is driven by a high demand from municipalities and industry for the Hope River (Kingston Basin), and irrigation needs in other locations (Rio Cobre and Rio Minho) (ESL Management Solutions Limited, 2009). The threshold for a water-stressed catchment is a demand-to-resource percentage of 40% (ESL Management Solutions Limited, 2009). The areas of the Hope River, Rio Cobre, and Rio Minho all fall into this category. The Hope River, which services the Kingston Basin, had a water deficit of 13 million cubic meters per year (m$^3$/yr) in 2005 (ESL Management Solutions Limited, 2009). This deficit is currently addressed through a water-supply transfer from the Rio Cobre and Yallahs basins. This strategy, however, may not be viable under changing conditions due to climate change. The Rio Cobre is expected to have a deficit of 40 million m$^3$/yr from 2050 and a deficit of 100 million m$^3$/yr from 2080 (ESL Management Solutions Limited, 2009).

A scarce water supply is one in which available water is less than or equal to 1,000 m$^3$/capita/year (Walling et al. 2005). Although Jamaica’s internal renewable water resources provide 3,651 m$^3$/capita/year, increased drought due to climate change undermines Jamaica’s water comfort. Of Jamaica’s total water use, 49% is used by agriculture, 17% by industry, and 34% for domestic purposes. Total domestic water consumption was 293.6 million m$^3$ in 2007 (ESL Management Solutions Limited, 2009).

Table 1 Average Annual Rainfall for Jamaica.

<table>
<thead>
<tr>
<th>Average Rainfall (mm)*</th>
<th>Present*</th>
<th>2050</th>
<th>2080</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,861</td>
<td>1,396</td>
<td>1,117</td>
</tr>
</tbody>
</table>


The following questions are answered given the aforementioned rainfall data, the total Jamaican land area of 10,990 km$^2$ (Aquastat, 1997), and assuming a stable Jamaican population (around 2.7 million island-wide and around 670,000 in Kingston), an average household size of five people, a roof-runoff
coefficient of 0.9, an average roof size of 80 square meters (m²) (CEHI, 2010), and using 2000 as a point of reference for the average of the 30-year mean rainfall data.

1. **Q:** Can domestic RWH meet the total domestic water consumption of roughly 300 million m³/yr today and in future years?

   **A:** When it comes to household-water consumption, domestic RWH can provide nearly a quarter of water demand today and up to 15% of demand by 2080 (since, as the climate heats up, less recoverable water will fall). See Table 2.

   2. The following two questions relate to catchment area and the ability to meet Jamaica’s water consumption (e.g., demand). The findings indicate that space is a limiting factor for meeting water demand through rainwater catchment area methods, but improvements can be made to increase catchment sizes.

   a. **Q:** How much additional catchment area is needed at the household level to meet Jamaica’s water demand of 94,000 MI?

   **A:** Assuming an average household roof-runoff area of 80 m², a catchment-area increase of 30% per household is needed today, and more in the future given the projected reductions in rainfall due to climate change. See Table 3.

   b. **Q:** How much land area, in km², would be needed for Jamaica to meet its entire water demand by RWH (annual water consumption set to about 94,000 MI)?

   **A:** There is technically not enough land area to harvest rainwater for all of Jamaica’s water demand. See Table 4.

3. **Q:** For Kingston area residents, can domestic RWH meet the river-water deficits of today and the future given climate-change predictions?

   **A:** Today, domestic RWH can meet the river-water deficit for the Kingston area (Hope River deficit). When climate-change predictions are taken into account, RWH can help alleviate the deficit (Rio Cobre water deficit) covering around 27% in 2050 and 9% in 2080. See Table 5.

### Discussion and Limitations

The limitations of this study are linked to its scope: (1) an overview of the climate-change impacts on water resources in Jamaica and (2) answers to overarching questions regarding the annual RWH potential in Jamaica. This analysis was geared primarily towards RWH from household rooftops, but

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Table 2 Annual Domestic RWH Potential.

<table>
<thead>
<tr>
<th>Target/Year</th>
<th>2000</th>
<th>2050</th>
<th>2080</th>
</tr>
</thead>
<tbody>
<tr>
<td>RWH potential (m³/yr)</td>
<td>72,500,000</td>
<td>54,400,000</td>
<td>43,500,000</td>
</tr>
<tr>
<td>% of domestic water consumption</td>
<td>24%</td>
<td>18%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Table 3 Household-Catchment Area Needed to Meet Jamaica’s Total Annual Water Demand.

<table>
<thead>
<tr>
<th>Target/Year</th>
<th>2000</th>
<th>2050</th>
<th>2080</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catchment area needed (m²)</td>
<td>104</td>
<td>138</td>
<td>173</td>
</tr>
<tr>
<td>% Increase from 80m² baseline</td>
<td>30%</td>
<td>73%</td>
<td>116%</td>
</tr>
</tbody>
</table>

Table 4 Area of Runoff Needed for RWH to Meet Jamaica’s Total Annual Water Demand.

<table>
<thead>
<tr>
<th>Target/Year</th>
<th>2000</th>
<th>2050</th>
<th>2080</th>
</tr>
</thead>
<tbody>
<tr>
<td>RWH runoff area (km²)</td>
<td>56,100</td>
<td>74,800</td>
<td>93,500</td>
</tr>
<tr>
<td>% of Jamaican land area required</td>
<td>511%</td>
<td>681%</td>
<td>851%</td>
</tr>
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Table 5 Percentage of Kingston Area Water Deficit Potentially Covered by Domestic RWH.

<table>
<thead>
<tr>
<th>Target/Year</th>
<th>2000</th>
<th>2050</th>
<th>2080</th>
</tr>
</thead>
<tbody>
<tr>
<td>River water deficit (m³/yr)</td>
<td>-13,000,000</td>
<td>-40,000,000</td>
<td>-100,000,000</td>
</tr>
<tr>
<td>RWH potential (m³/yr)</td>
<td>14,600,000</td>
<td>10,960,000</td>
<td>8,760,000</td>
</tr>
<tr>
<td>% of deficit covered by RWH</td>
<td>112%</td>
<td>27%</td>
<td>9%</td>
</tr>
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</table>
many other buildings (e.g., educational, commercial, governmental) could be used. Different forms of catchments are also available, including land-surface catchments. In the parish of St. Ann, for example, there are community rainwater collection systems using slanted concrete areas on hillsides (Parchment, 2011). Many important elements of implementing a RWH system are beyond the scope of this work (such as purposes for which rainwater may be used, system design, and water-purification options). Yearly averages are used in the assessments, while monthly differences are useful for dry-spell management.

The results from this analysis are oriented around island-wide rainfall (with the exception of one example from the Kingston area), but a parish-by-parish vision is also helpful given the geographical differences in rainfall patterns. Figure 3 shows the differences between the high rainfall parish of Portland and two low rainfall parishes—Clarendon and St. Ann. Essentially, the figures presented in this study will be higher for rain-abundant areas and lower for drought-prone areas. This analysis thus serves as a policy guide for mitigating the risk of drought with climate change. Other parts of the solution will include increased water efficiency across all industries, reclaimed water use, sustainable management of surface and groundwater, and innovative technologies. Public policies can target the drought-prone areas of Jamaica since they are the most critical. For example, pilot projects and policies that require RWH for new buildings, tax incentives for installing RWH collection devices, and public building retrofits, can be targeted first to parishes with the largest water deficit.

To optimize space use, technical innovations such as combining RWH with the implementation of solar panels can be put into practice.

Conclusion

As the Jamaican proverb states, “When water trowweh I’ cyaa pick up,” [When water is thrown away, it cannot be picked up]. This adage indicates the precious status of water as a necessity not to be wasted. Even more so with climate change, SIDS must find ways to cope with less water availability. This study shows quantitatively the benefits and limitations of RWH. The Jamaican government currently allocates 0.1% of its total budget to water resources (ESL Management Solutions Limited, 2009). Policy initiatives, such as RWH mandates for all new construction and tax incentives to incorporate RWH into existing structures, are necessary to mitigate and adapt to the impacts of climate change on water resources. Given the economic importance of the tourism industry and the large quantities of water associated with it, policies could target hotels and buildings in the tourism sector for rainwater collection (i.e., rainwater can be used for laundry, flushing toilets).

The lessons learned from analyzing the Jamaican case study may be relevant to other SIDS, especially those expected to experience similar decreases in precipitation due to anthropogenic climate change. For example, a recent study shows that the dry season will become drier and the wet season will become wetter in the Seychelles; the increase in dry spells that resulted in drought conditions in 1999 are likely
to occur under future climate change (Payet & Agricole, 2006). This trend in the Seychelles may call for more RWH to store water for later use during the dry spells. In Barbados, the fifteenth most water-scarce nation in the world, water availability is directly influenced by rainfall (80% of which is lost via runoff and evapotranspiration); rainfall is also expected to decline due to climate change, and saline intrusion of wells is anticipated to increase due to sea-level rise and low rainfall (Emmanuel & Spence, 2009). Seawater desalination using renewable energy has been recommended for some SIDS and may be critical to survival when combined with other adaptation methods such as RWH.

While SIDS account for less than 1% of global greenhouse-gas emissions (MACC, 2010), they risk bearing the brunt of climate-change impacts. Low-lying island atolls, such as Tuvalu and Kiribati in the Pacific Ocean and the Maldives in the Indian Ocean, are particularly at risk; most or all of their habitable land may be lost due to sea-level rise and erosion (Tisdell, 2008). Tuvalu has announced that its 11,000 citizens will have to leave permanently because they will not win the battle with sea-level rise (MACC, 2010). Hopefully, many SIDS will be able to effectively mitigate, adapt, and survive. Solutions to climate-change impacts on water resources will be key in this survival.

References